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# FUNCTIONALITY OF THE MEASUREMENT AND VERIFICATION SPECIALIST

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ONLINE TRAINING BY KRISHNAJI PAWAR

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MODULE  
**18**

# Sample M&V Plan

KRISHNAJI PAWAR - CEO & FOUNDER

LEED AP(BD+C), GSAS CGP, GCP, ISO 14001

[WWW.BEYONDSMARTCITIES.IN](http://WWW.BEYONDSMARTCITIES.IN)





# FUNCTIONALITY OF THE MEASUREMENT AND VERIFICATION SPECIALIST

Measurement and Verification (M&V) is a crucial process in evaluating energy efficiency projects, providing a framework for determining actual energy savings compared to a baseline scenario. An effective M&V plan quantifies energy savings and validates the performance of energy efficiency measures over time, ensuring transparency and accountability for stakeholders.

# Learning Objectives

- Instrument metering and calibration
- Fieldwork: formal accreditation, safety, OSHA, and NFPA
- Data accessibility, communication, and valuation
- Reporting on Measurement and Verification (M&V) Projects
- Definitions of IPMVP Options
- The future of measurement and verification
- **Sample M&V Plan**
- **Sample M&V Report**
- ESCO's Guide to Measurement and Verification
- Summary and Resources



# INTRODUCTION

- M&V is a systematic process used to evaluate energy efficiency projects, renewable energy installations, or initiatives aiming to reduce resource consumption.
- The primary goal of an M&V plan is to provide credible data demonstrating actual savings or benefits.
- A well-structured M&V plan ensures transparency, accountability, and confidence among stakeholders.
- Key components of an effective M&V plan include objectives and goals, baseline measurement, methodology, data collection and analysis, reporting and verification, and adjustments and revisions.

# MEASUREMENT AND VERIFICATION (M&V) OVERVIEW

- Objectives and goals define what is to be measured and why it is significant.
- Baseline measurement is crucial for comparison purposes and can include methods like Retrofit Isolation, Whole Building Measurement, or Engineering Calculations.
- Data collection and analysis specify the duration and frequency of data collection and analysis.
- Reporting and verification communicate findings to stakeholders.
- Adjustments and revisions address handling unforeseen circumstances or changes in project scope.
- A well-constructed M&V plan is essential for validating the performance of energy efficiency and renewable energy projects.



# COMPONENTS OF A SAMPLE M&V PLAN

- Objective of M&V: The objective should clearly communicate the purpose and scope of the evaluation.
- Baseline Conditions: The baseline represents the energy consumption pattern before the implementation of energy efficiency measures.
- M&V Methodology: The methodology outlines the techniques and protocols used to measure and verify energy savings.
- Data Collection Procedures: The procedures detail the processes involved in gathering and analyzing data necessary for the M&V effort.
- Reporting and Documentation: The section outlines the format and frequency of reports, as well as the key performance indicators (KPIs) that will be reported.
- Quality Assurance and Quality Control (QA/QC): The section details the steps taken to verify data accuracy and the methods for addressing any discrepancies.
- Budget and Resources: The section outlines the financial and human resources required to implement the M&V plan.



# SUMMARY

- A well-structured M&V plan is vital for accurately assessing the performance of energy efficiency projects and ensuring stakeholders can trust the reported savings.
- The M&V process serves as the backbone of any energy efficiency project, providing evidence needed to justify investments and promote further advancements in the field.



**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



Middle East Centre for Sustainable Development (MECSD)  
Technopark, Sheikh Zayed Rd.,  
P.O.Box No. 37316, Dubai, United Arab Emirates  
Tel.: +971 4 8869000 Fax: +971 4 8869001  
Email : [info@mecsd.com](mailto:info@mecsd.com)  
Website: [www.mecsd.com](http://www.mecsd.com)



## 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 the 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



### *Measurement and Verification Plan*

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



*Measurement and Verification Plan*

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 Facility 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.



*Measurement and Verification Plan*

Table 2: Schedule of Reporting Activities

Item	Recommended submission time	of 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 & Names	Contact 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	MECS D	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



### Measurement and Verification Plan

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
<b>Total Energy</b>	<b>550,641</b>	<b>422,612</b>
<b>Total Cost</b>	<b>166,108 (AED)</b>	<b>123,863 (AED)</b>

#### 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



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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 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 U – 0.52, SHGC –
Windows	U – 1.22 , SHGC – 0.25	0.26 0.089
Walls (U-value)	0.12 4	10.4 (average)
HVAC System (Split Ducted Units)	9.3	0.75 (average)
Lighting Power Density	0.96 (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



### *Measurement and Verification Plan*

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.



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**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	
Latitude	
Longitude	
Elevation (Feet)	Abu Dhabi, UAE
Heating Deg Days (Baseline 650F)	40.97°N
Cooling Deg Days (Baseline 500F)	28.82°W
Heating Design Temp	764
Cooling Design Dry bulb	3,534
Cooling Design Wet bulb	3,777
ASHRAE Climate Zone	26°F
	84°F
<b>6.4</b>	69°F
	1A

**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



### Measurement and Verification Plan

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 Government weather agencies are Baseline and as-built building simulation models. 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:

$$ERR_{\text{month}}(\%) = \frac{M - S_{\text{month}}}{M_{\text{month}}} \times 100$$

$$ERR_{\text{month}} = \sum_{\text{year}} \frac{ERR_{\text{month}}}{N_{\text{month}}}$$

where  $M$  indicates the measured kWh or fuel consumption and  $S$  the simulated kWh or fuel consumption.  $N_{\text{month}}$  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:



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

The mean of the monthly utility bills is:

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

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

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

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.



### *Measurement and Verification Plan*

If it is so desired at anytime by the owner to perform an analysis of the building's energy consumption (for the purpose of identifying significant equipment or system performance degradation) it is recommended that the following approach be used to estimate building energy consumption.

Use the as-built simulation model as a "baseline" model for subsequent M&V periods.

Make the necessary adjustments to the as-built simulation model. This includes providing weather data and changes in operational and occupancy schedules for the M&V period. Subtract the metered building energy use from the energy use of the adjusted as-built simulation model. Any considerable degradation in physical equipment or system

performance will be reflected in significant energy losses.

Since it is known that new equipment will be added in the future it will be necessary to completely recalibrate the as-built and Baseline simulation models for each subsequent M&V period in which additions are made.

Make the necessary adjustments to the Baseline and as-built simulation models. This includes providing weather data and changes in operational and occupancy schedules for the M&V period.

Any alterations made to the building which may affect the energy consumption such as additional construction, changes in equipment or additions of new equipment must be accounted for both the simulations. Keep in mind that for "savings estimates" the Baseline simulation model will need to incorporate the minimum values for materials and equipment as required by ASHRAE 90.1-2004.

For recalibration of the as-built and baseline models simply follow the calibration procedure described above.

Once the simulation models are recalibrated an energy consumption analysis can be performed by subtracting metered post-construction energy use from the energy use of the recalibrated as-built simulation model.

Significant physical degradation in equipment or system performance will be detected in the recalibration process.



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Recommendation If it is so desired by the owner to perform subsequent energy analysis, it is strongly recommended that owner's personnel receive formal training on the simulation software prior to use.

#### **6.5 Model Calibration**

Both the as-built and baseline simulation models are to be calibrated, with the as-built model being calibrated first. This requires adjusting model inputs so they are consistent with operating conditions. These adjustments will primarily involve changes to scheduling and occupancy, but may involve equipment if variances (with design parameters) are found in actual performance.

At the beginning of the M&V period the following operational conditions will be analyzed as part of the calibration process:

- weather
- occupancy
- system operating parameters

#### **6.6 Simulation Accuracy**

Accuracy of the simulated baseline and savings estimation is affected by many factors. The following factors should be evaluated to identify potential sources of simulation error:

- Operational stability of building
- Limitations of simulation software to adequately model ECMs and building systems
- Rigor of the simulation models
- Degree of calibration to operational conditions
- Similarity between the as-built and baseline models

Change orders or other modifications that may have occurred during construction will be reviewed prior to or during calibration.



### Measurement and Verification Plan

#### 7. Metering and Reporting

Meters are installed within the building to track electricity and water usage. Meters will be closely monitored, utility demand and consumption will be recorded. Data collected will be logged for analysis by the M&V project team. See Appendix B: Energy Meter Line Diagram and Appendix C: Water Meter Line Diagram Monitoring of performance enables tracking of energy and water consumption in real time, spotting potential trouble spots and fixing them before they turn into major sources of energy loss or inefficiency. The data collected will enable the building to identify when performance departs from normal values, alerting maintenance personnel to look for things like malfunctioning valves, dampers, etc.

##### 7.1

#### Monitoring Points

The following table provides information on equipment to be monitored, and method of data collection.

Table 7: Equipment and Data Collection

Equipment	Data Monitored	Data Collection
HVAC Systems & Lighting	Energy consumption	Energy meter
Water / Plumbing	Water consumption	Water meter

##### 7.2 Data Collection and Reporting

Data for M&V will be collected by facility staff through the meters or portable metering devices (if needed). Data collection and meter reading should be witnessed by an owner representative.

The following data and analysis will be completed:

- Gather data on building systems to determine equipment and ECM performance;
- In conjunction with the M/S Walls & Floors ME FZCO & Section's facility engineers evaluate trend data to identify areas that are more energy intensive;



### *Measurement and Verification Plan*

- 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<sup>2</sup> per month (e.g., 5,000 BTUH per m<sup>2</sup> 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.*



## APPENDIX A: ANNUAL MEASUREMENT & VERIFICATION REPORT



APPENDIX A

Water Consumption System & Solar Water Heater						
M/S Walls and Floors ME FZCO						
Plot No. S20905, JAFZA, Dubai, UAE						
ANNUAL MEASUREMENT & VERIFICATION REPORT						

from DEWA (water consumption) Gallons 574,895 (kWH/yr)

Measurement to be Monitored DATA e person  
Energy Conservation Units Measurement Review Baseline Actual Responsibl

kWH/yr mounted on the Monthly measured manageme

Water flow in Filter Facility meter To be Facility  
permanent water Monthly measured manageme

Submitted by:

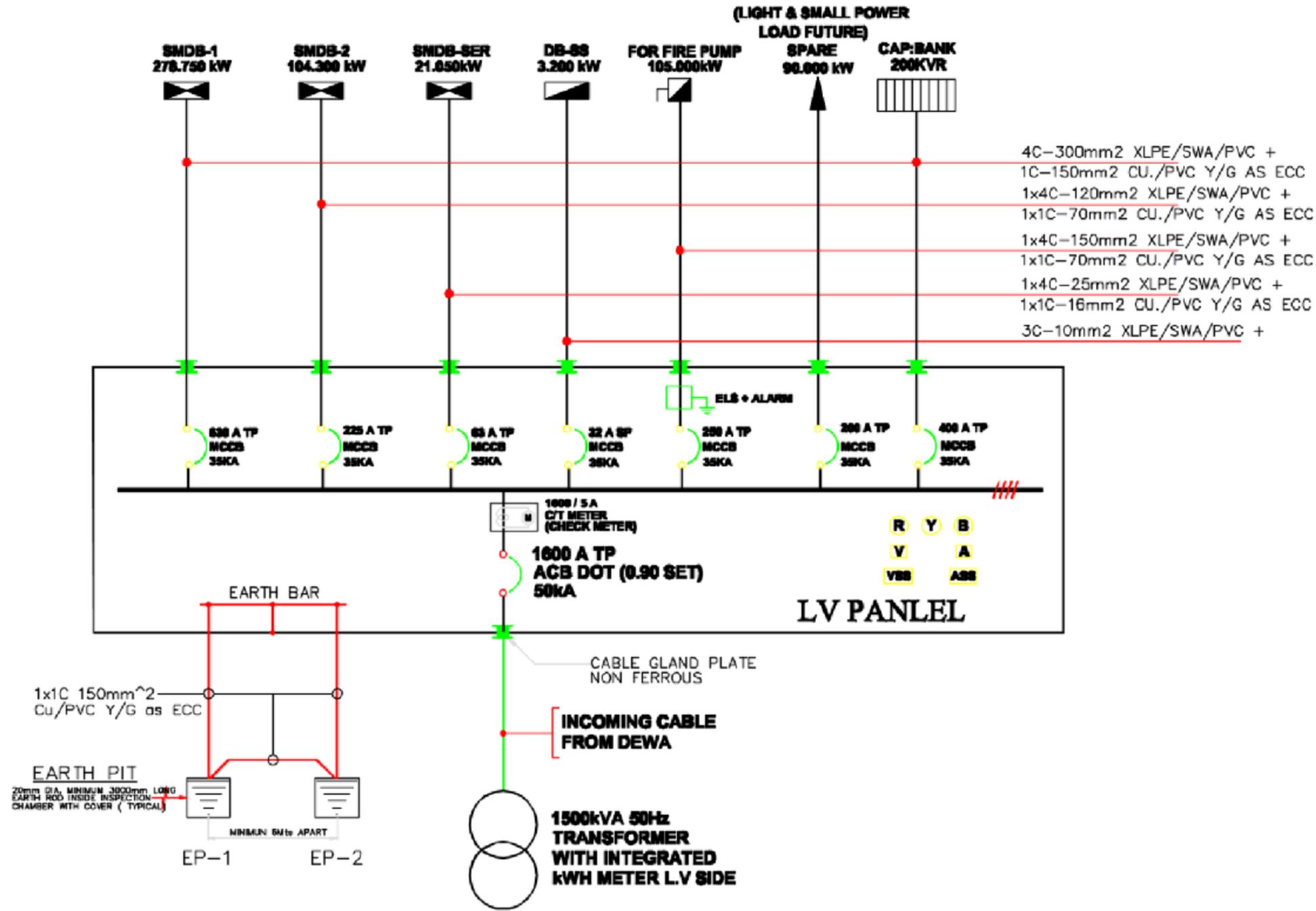
Submitted to:

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Facility Manager

\_\_\_\_\_  
Green Building Department



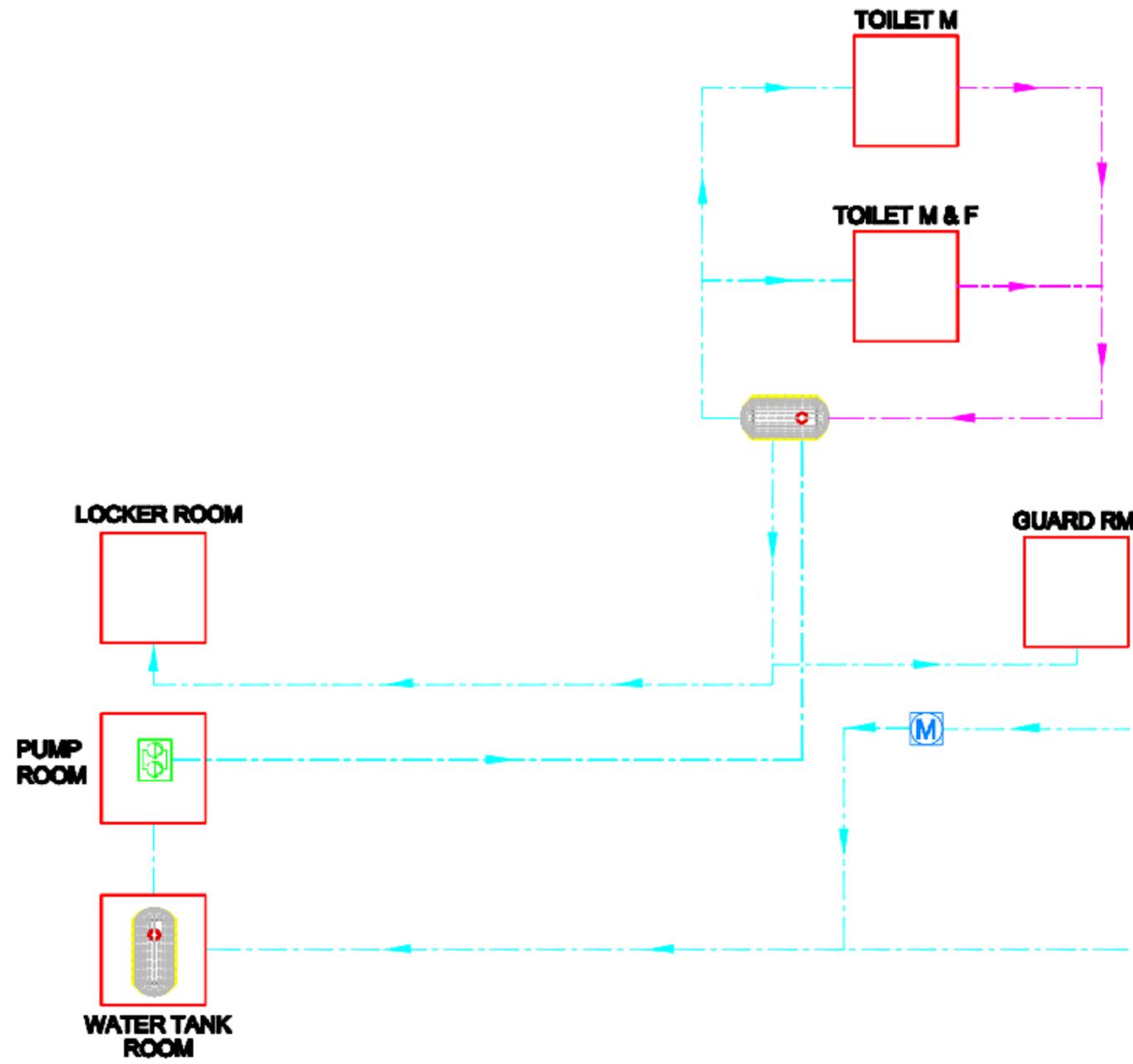
## APPENDIX B: ENERGY METER LINE DIAGRAM



**ENERGY METER LINE DIAGRAM**



## APPENDIX C: WATER METER LINE DIAGRAM

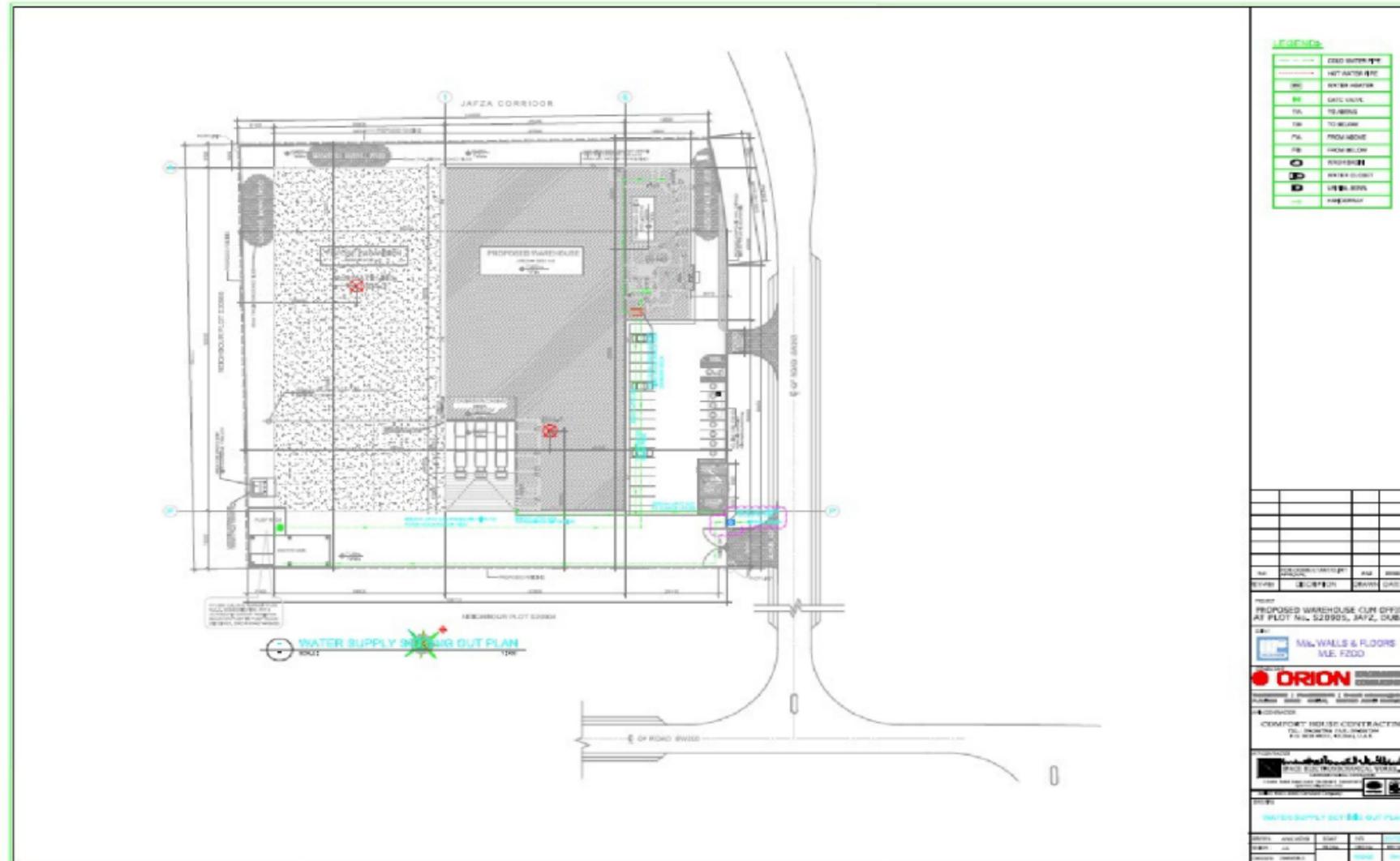


WATER LINE DIAGRAM



## APPENDIX D: AS-BUILT DRAWINGS





AS-BUILT WATER SUPPLY LAYOUT- Showing the location of the water meter

# CONTACT US



+91 6363032722



info@beyondsmartcities.in



learn.beyondsmartcities.in



#55,HMR Layout ,Bengaluru ,India



# THANK YOU

