Energy Performance Measurement and Verification

Guidance on Data Quality

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Sections generally follow the sequence in which measurement & verification (M&V) practitioners should consider key issues:

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Energy Performance Measurement and Verification:

Guidance on Data Quality

A. INTRODUCTION

The measurement and verification (M&V) of energy performance improvements is an important method to determine and report on the value of an implemented energy conservation measure or project. M&V *data quality* is a particularly important aspect for M&V practitioners to consider in order to guarantee the credibility of reported energy performance, which is of the utmost importance to ensuring investor and stakeholder confidence in the reported results.

This document seeks to provide assistance and guidance to global M&V practitioners, resulting in increased stakeholder confidence in M&V data quality and more informed decision making when analyzing and interpreting measured or derived M&V data. This document does not seek to globally standardize data quality, issue prescriptive guidelines, or attempt to cover all of the M&V protocols and methodologies that may be used. Rather, the aim is to help make M&V reporting more comparable across the Global Superior Energy Performance Partnership (GSEP) countries and globally. International comparability of results not only enables countries to more effectively share results with one another, it also facilitates improved knowledge sharing regarding the challenges and successes a facility or country may have faced while implementing M&V. Accordingly, the target audience for this document includes all M&V practitioners within the GSEP countries, as well as the wider global M&V community.

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B. RECOMMENDED M&V DATA QUALITY FRAMEWORK: SUMMARY

Different countries or project stakeholders may want to have access to a variety of information relevant to any implemented energy performance improvement measures. However, it is important to enable comparisons between reports of various countries, projects and stakeholders. The suggested minimum or basic M&V reporting measures are stated below with a clarification thereon.

M&V Measures to Report on:

- Energy (MJ, MMBtu, MWh, etc.)[1]
- Energy type (LPG, electricity, coal, etc.)
- Date and time of occurrence

[1] The exact unit of measure is not critical, because units can always be converted (e.g., IEA unit converter: http://www.iea.org/stats/unit.asp) to whatever unit is required.

M&V Reporting Format:

- Energy performance for every hour, 24 hours per day, 365 days per year.

M&V Data Quality Definition:

- The quality of M&V reporting should be to an accuracy level, confidence level, and cost acceptable to all stakeholders involved.

M&V Data Quality Level:

- All reported performance should be conservative in nature (i.e., performance improvements should never be overstated). Doing so gives assurance to all stakeholders that the reported performance can be trusted.
- The reported performance should always be stated with a statistical relevance. Statistically, performance with ±7.5% accuracy (or precision) and 80% confidence is recommended, but this may change depending on project specific conditions. (These statistical measures are directly related to the accuracy of measurements performed and the sample size used.)

M&V Costs:

- Typically M&V costs range between 5% and 10% of total project costs.

C. DETERMINING MEASURES TO REPORT ON

A key early step in the M&V process is to identify and define data measures to report on. Primary measures to report on include (1) energy consumption (both pre- and post-energy efficiency project implementation), (2) the type of energy consumed, and (3) the date and time of energy performance improvement. The M&V process should allow for values or trends for major but relevant variables. For example, if the baseline is normalised for production, the M&V process may report energy savings despite an absolute increase in energy consumption.

A key early step in the M&V process is to identify and define data measures to report on.

Determining which (if any) additional measures to consider depends on the M&V objective (i.e., what the stakeholder wants to gain from M&V). Therefore, strictly defined measures cannot be universally designated for all companies or countries. For example, environmental considerations may hold more weight in certain countries, while other countries may emphasize reporting on financial measures.

Other reporting measures can be categorized into seven groups, as shown in the table below, with examples of each group of measures. This is not an exhaustive list of reporting measures; others exist.

Table 1: Groups of reporting measure categories, with examples

Reporting Measure Category	Reporting Measure Examples
Environmental Measures	Air, water, and atmospheric impacts
Social Measures	Health benefits, program participant free-ridership impacts
Economic Measures	Job creation, governance and community impacts
Financial Measures	Project payback, internal rate-of-return, and return-on-investment
Location, Sector, or Initiative Measures	National, regional, and municipality impacts
Project Stage Measures	Funding approval stage, scoping/M&V plan/baseline stage, and performance
Engineering Measures	Energy demand or consumption, technology feasibility, and equipment efficiency

D. M&V REPORTING FORMAT AND REPORTING PERIODS

Even at early stages in the M&V process, the reporting format is a key focus in order to ensure that the correct M&V measures are considered for implementation. For example, an M&V practitioner might ignore the need for continuous measurements initially, only to find later that facility equipment usage profiles or processes change regularly.

The reporting format is a key focus in order to ensure that the correct M&V measures are considered for implementation

The M&V reporting format is based on the period of time in which measurements are considered. The assessment date is defined as the end of the assessment period, which can be considered on a monthly, yearly, year-to-date (YTD), or inception-to date (ITD) basis. It is most important that all stakeholders have a similar understanding as to the scientific definitions for these periods. In order to develop an acceptable M&V report, M&V practitioners must first designate which assessment period is most applicable. In addition, the time of use (TOU) periods—a metric that differentiates energy loads based on the time of day and week or between high and low rate periods—must also be considered. ***The recommended time period that makes up the reporting format for GSEP purposes is based on facility energy performance for every hour of every day for a full year.***

E. DEFINITION OF DATA QUALITY

An overarching issue to consider is the overall approach to report performance. Some M&V reports can adopt an aggressive stance and attempt to document average or optimistic performance. In these cases, reported performance will sometimes be either higher or lower than the actual performance and thus cannot be guaranteed. This could negatively affect the credibility of the facility, company, and M&V team.

A conservative M&V approach must be taken in order to guarantee reported performance–this means that reported energy performance must never be overstated. Guaranteed performance is critically important because it provides credibility to the facility, energy efficiency projects, M&V team, etc. Guaranteed performance reporting also makes it easier to perform benchmarking, compare performance across projects, identify reasons for differences, and mitigate any potential disputes.

The following are characteristics that must be managed in order to guarantee reported energy performance and the credibility of the reported energy performance:

- **Instrumentation** will never be 100% accurate. Measurement equipment errors can be due to calibration issues, inexact measurements, or improper meter selection installation or operation.
- **Modelling** is important to manage due to difficulties in finding mathematical forms that fully account for all variations in energy use. Modelling errors result from inappropriate functional form, improper inclusion of irrelevant variables, or exclusion of relevant variables.
- **Sampling** can introduce errors that result from the variation in values within the population (biased sampling). Sampling should be performed in either a physical sense by designating a certain number or percentage of physical energy consuming items (e.g., lighting fixtures) or a temporal sense by defining a number of measurements taken per unit of time (e.g., instantaneous measurement only once per hour).
- **The interactive effects** of actions implemented within the system (measurement) boundary but affecting the larger organizational boundary may not be fully included in a performance computation methodology**.** For example, changing a lighting system to be more efficient will have a measurable effect on the HVAC system. If the measurement boundary encompasses the lighting system only, the effect on the HVAC system must be considered separately.
- **Estimation of parameters** can also be performed using an M&V retrofit option, rather than measuring all parameters. In other words, performance is determined by partial short-term or continuous energy use measurements, separate from the overall facility energy use (with some stipulations). For example, boiler pre- and post-retrofit efficiencies are measured and operating hours are stipulated or based on interviews. Additional characteristics to be managed include errors resulting from any computing or calculations and the overall M&V plan and/or methodology errors.
- **Uncertainty management** refers to managing the data quality to a level where the results would be acceptable. Models may be developed and used to establish optimal measurement samples against the benefits generated.
- **M&V costs** are usually directly related to the quality and amounts of data available to be used. However, more data does not always imply substantially better results. The availability of more data, with the additional cost involved, should therefore always be consideration.

Measurement equipment errors and measurement cost limitations will always result in measurement uncertainties. Uncertainty management takes into consideration the effects of uncertainty, which makes it possible to report with certainty. With due regards to the M&V objective and the intended use of the results, there is a compromise between uncertainty levels and M&V costs, because decreasing the uncertainty would bring about more measurement requirements with more data, which ultimately results in more expensive M&V. As long as uncertainty is considered, the exact quantification of uncertainty may not be required if achieving it is prohibitively expensive in relation to the value of the energy performance measure. For the same reason, formal calibration of measurement equipment and traceability of measurement may not be required.

F. M&V APPROACHES

The level of required M&V, along with the associated costs, is a deciding factor in which M&V approach to consider. Some of the known M&V approaches that can be used to develop appropriate methodologies to quantify the energy performance with a specific level of certainty and confidence are shown in the following table:

Table 2: M&V approaches, with typical applications and performance calculations

M&V Approach	Typical Performance Calculations	Typical Applications
1. Retrofit Isolation **1.1 Key Parameter Measurements (Partial Retrofit Isolation)** Performance is determined by partial short-term or continuous field measurements (i.e., metering) of only key parameters of the applicable system energy use, separately from the rest of the facility.	Engineering calculations using short-term or continuous measurements and stipulations.	Boiler pre- and post-retrofit efficiencies are measured and operating hours are stipulated or based on interviews.
1.2 All Parameter Measurements (Retrofit Isolation) Performance is determined by short-term or continuous field measurement (i.e., metering) of the applicable system energy use, separately from the rest of the facility.	Engineering calculations using short-term or continuous measurements.	Air conditioner pre- and post-retrofit energy use is determined by short- term or continuous measurements of applicable systems.
2. Whole Facility Performance is determined by measuring energy use at the facility level. Short-term or continuous measurements are taken during the post-retrofit period.	Regression analysis of whole facility utility meter or sub-meter data.	Energy management system performance is based on a regression analysis of utility billing data for pre- and post-retrofit periods.
3. Calibrated Simulation Savings are determined through simulation of energy use components or the whole facility and are calibrated to pre- and/or post-retrofit utility billing data.	Energy use simulation, calibrated with monthly utility billing data.	Weather-sensitive measures with pre-retrofit billing data and post- retrofit energy use. Or novel applications such as an installation in a large, customized plant.

Each of these M&V approaches will require different data measurement requirements, which will have different cost implications. In some instances the stakeholders may be willing to accept a higher degree of uncertainty by discounting performance in order to lower the overall cost of M&V. Note, since conservative reporting is mandated, the only way to accept higher uncertainty is to discount the performance figures. In addition, M&V data quality is highly dependent on measurement timing and measurement duration. The measurement methods that can be used to address any of these M&V approaches can be categorized into the following four groups:

Table 3: M&V measurement methods (not an exhaustive list), with typical applications and costs

Measurement Method	Description	Applicable Energy Conservation Measures (ECMs)	Well Suited For…	Typical Cost (% of ECM Costs)
Spot Measurement	Measurements are taken when and where appropriate. Operational factors such as lighting operating or cooling hours must be stipulated to reach accurate results.	Projects with a constant load (e.g., lighting, electric motor replacements, and road vehicles).	Small projects (M&V cost difficult to justify), fast-track projects, projects where installation verification is most important, and projects where owner and stakeholders are willing to assume some performance risk.	**1% – 5%** Primarily dependent on the quantity of measurement points and the type of measurements required.
Continuous Measurement	Measurements are taken continuously throughout the term of the contract at the equipment or system level.	Variable load projects, projects with devices and systems that can be isolated, or projects where few measurement points are needed (e.g., chiller, boiler, HVAC, and control system).	Large projects that can absorb the higher M&V cost, projects with time available for baseline measurement, projects where owner and stakeholders are *not* willing to assume performance risk, or projects with operational reasons to collect data that were not previously collected (e.g., for improved quality control).	**3% – 10%** Primarily dependent on the quantity and type of system(s) to be measured and the duration of metering and analysis.
Utility Bill Comparisons	A versatile high-level M&V approach where all ECMs within a metered building or group can be measured and analyzed by using current and historical utility meter/sub-meter data.	Any measures within a metered building, facility, or group. Individual ECMs implemented cannot be reported on, but reporting can be done on the building, facility, or group level.	Projects where energy performance improvement is projected to be greater than 10%–20% of baseline energy use, aggregation of various ECMs within a metered building or group, fast-track projects, or projects where stakeholders are *not* willing to assume performance risk.	**1% – 10%** Primarily dependent on the quantity and complexity of parameters analysed.
Calibrated Simulation	The most versatile approach, where performance is determined through simulation of facility components and/or the whole facility where all ECMs can be applied. Actual measurements from before or after the ECM implementation are used to calibrate the simulation model.	All.	Projects with no available metered data; large projects that can absorb the higher M&V cost; aggregation of various ECMs within a metered building, facility, or group; fast-track projects; projects with anticipated future baseline adjustments; new construction; and projects where stakeholders are willing to assume performance risk.	**3% – 10%** Primarily dependent on the quantity and complexity of systems being evaluated.

To validate the measurements taken by means of the four approaches described, periodic audits and data reconciliation must take place. These audits can be performed either as a single, post-installation verification, or as a post-installation verification with regular interval verifications following completion of energy-efficient retrofitting to evaluate project sustainability and persistence of performance improvements. Baseline adjustments may also occur due to future changes within the facility and can "re-open" the M&V process, which may result in additional energy performance improvements. To promote transparency, such adjustments should be pre-established and incorporated into the M&V plan whenever possible.

G. DATA QUALITY VALUE VS. DATA QUALITY COST

No measurement instrument or sampling methodology is 100% accurate.

M&V data quality is directly proportional to M&V cost. A more detailed M&V approach will reduce the uncertainty associated with data measurements and accordingly increase data quality; however, it will also cost more money. While uncertainty can be improved to exceptionally high levels, 100% accuracy can never be achieved because no measurement instrument or sampling methodology is 100% accurate. The cost of determining energy performance depends on many factors; however, the following pertinent questions, among others, need to be addressed:

- For what purpose is this M&V being done (i.e. performance-based payments vs. "nice to have reporting")?
- What is the optimal balance between cost and data accuracy?
- What is an acceptable difference (error margin) between observed and actual reported energy performance?
- What are all of the benefits of achieving a higher accuracy level?
- To what extent are the stakeholders willing to discount performance in order to accommodate uncertainty?
- Are there any operational reasons to install metering (e.g., pressure monitoring for improved safety or control)?

The expectations and needs of all stakeholders need to be clearly defined and well understood before initiating a project.

It is vital to not decrease M&V costs to the point where the performance is discounted to a level where the data effectively loses all value. On the other hand, attention must be paid to ensure that the cost (and proportionally the value) does not reach levels that exceed the expectations of all stakeholders involved. As a result, the exact expectations and needs of all stakeholders need to be clearly defined and well understood before initiating a project. The key is to understand what level of M&V data quality (i.e., precision and confidence levels) would meet, but not unnecessarily exceed, these needs.

Benchmarks defining how much money should be invested to conduct M&V vary. For example, the IPMVP recommends no more than 10% of annual project monetary savings, while Japan and South Africa recommends no more than 5% of total project costs. However, most importantly, the total project cost (including M&V costs) needs to be acceptable to project stakeholders. M&V costs should reflect the objective of the stakeholders, regardless of whether the M&V is used for performance contracting, incentives, etc. M&V costs are also dependent on other considerations, including the amount of savings involved, overall project costs, project complexity, equipment needs, geographical spread/positioning, experience level of the M&V team, supply and demand on M&V, etc.

An example that illustrates the relationship between data quality value and data quality cost is shown in a reference document titled "*Optimal Sampling Plan for Clean Development Mechanism Energy Efficiency Lighting Projects*.", reference 16 at the end of this guidance document.

H. STATISTICAL METHODS

A variety of statistical methods for quantifying, evaluating, and reducing uncertainties are used in M&V reporting. Some of the objectives for using statistical methods are to evaluate the quality of available data, to evaluate the relationship between specific sets of data (in order to obtain a suitable energy variable to use for adjusting M&V baselines), to check and ensure that credible results are being reported, amongst other objectives. The most important objective for using statistical methods is to clearly indicate the credibility, or uncertainty level, of the reported energy performance. To achieve this objective, the accuracy of a reported value is expressed as the range within which the true value is expected to be with some level of confidence.

Statistical methods are used to clearly indicate the credibility, or uncertainty level, of the reported energy performance

Many sources of information exist for determining processes and methodologies to establish statistical precision and confidence levels that are scientifically and financially acceptable. While planning for M&V projects, M&V practitioners should actively seek to find the precision and confidence levels with which stakeholders would be most comfortable in reporting the ultimate performance achieved. Other examples of statistical methods are shown in a referenced document named "Statistical methods reference" reference 16 under the heading "References".

Once the factors of influence (energy variables) are identified, the relationship between these drivers and energy consumption (or production) can be established by a technique known as regression analysis. Regression analysis attempts to describe the relationship between consumption (or production) and its drivers with a mathematical equation (i.e. model). An advanced or simple linear regression model may be used, as appropriate. Along with the regression model, an important step is the establishment of a baseline period for the analysis. Often, a time series graph is used to help identify the baseline. Once the baseline is set, it can be used to establish the "would have been" (i.e., modelled) energy consumption or production during a period for a specified set of conditions described by the variables. The analysis baseline period Then, the "would have been" usage (or production) can be compared with the actual; the difference between actual and "would have been" values is calculated for each period and added together, creating a "running total". This is referred to as the CUSUM, or CUmulative SUM, of the differences. The CUSUM is also referred to as the cumulative savings total.

I. UNCERTAINTY MANAGEMENT

The M&V accuracy of an energy performance improvement project is defined as the range within which the true value is expected to be, with some level of confidence. For example, a meter displaying consumption as 5,000 units with an accuracy (i.e., precision) of ±100 units, and a confidence of 95%, means that 95% of the readings of the same true value are expected to be between 4,900 and 5,100 units. This is an acceptable way of presenting and utilizing uncertainty (accuracy).

However, when developing an optimal M&V plan, uncertainty criteria or objectives (e.g., the preferred precision and confidence levels expected by stakeholders) should be clearly defined. M&V should then be planned to achieve these levels. It is important to recognize and report all uncertainty factors, either qualitatively (in situations where a number cannot appropriately describe an issue) or quantitatively (using the least number of significant digits).

As previously outlined in this document, the quality of the M&V reporting should be to accuracy (precision) and confidence levels acceptable to the stakeholders involved. However, since M&V is based on models that are intrinsically erroneous, the level of inaccuracy of the model will always be in question, even if the quality of the M&V report achieves the desired accuracy and confidence levels. It is therefore important to define reported performance in terms of confidence and precision levels that inform to the actual accuracy (or inaccuracy) of the reported performance.

As a result, a good/appropriate M&V report must decrease uncertainty to the confidence level required by all involved parties. However, increasing the detail taken during M&V can increase the potential for disputes and can even sometimes *increase* the level of uncertainty. Therefore, depending on the situation, simple M&V reporting may be more beneficial than very detailed M&V reporting. Overall, uncertainty is only unacceptable when it results in a potential loss of income or penalties. **A general recommendation is for data quality to be managed in such a way that the ultimate energy performance improvement has an accuracy of at least ±7.5%, with 80% confidence.** This may require that the data quality criterion be applied all stages, or specific stages, of the M&V process, e.g. the baseline period, performance reporting period, for specific parameters or the final savings.

In addition, an independent verifier may also be required to review the performance being reported. Although it is advisable that this review should be performed by a person with M&V knowledge, it could also be done by using a resource such as a Data Integrity Auditor, preferably with knowledge of the modelling methods being used (e.g., if a calibrated simulation is performed on an industrial furnace, the performance reviewer should have a good understanding of the merits of different approaches to heat transfer/thermodynamic simulations). This process usually starts by reviewing the M&V plan, then it involves evaluating if the proposed methodology was applied correctly, whether calculations are correct to acceptable standards/norms used, and if the reported performance are within the margins specified and can be considered conservative.

Uncertainty is a result of error, or the difference between observed and actual energy consumption. Factors that influence the level of uncertainty include sample size, meter distribution, measurement equipment calibration, modelling (linear regression and R2 value), and other unquantifiable human errors.

Precision is an assessment of the error margin of the final estimate. The confidence level is defined as the probability that any measured value will fall within a stated range of precision (IPMVP).

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The Global Superior Energy Performance (GSEP) initiative was launched in 2010 by the Clean Energy Ministerial (CEM) and International Partnership for Energy Efficiency Cooperation (IPEEC).

Through GSEP's Energy Management Working Group (EMWG), government officials worldwide share best practices and leverage their collective knowledge and experience to create high-impact national programs that accelerate the use of energy management systems in industry and commercial buildings. For more information, please visit: http://www.cleanenergyministerial.org/energymanagement.