Measurement and verification of utility driven DSM programmes: Best practices and case studies

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Abstract

This paper is the fourth in the series of background papers developed for the participants of the Utility CEO Forum on Demand Side Management (DSM).

Demand side resources constitute energy and demand savings resulting from the actions of a utility, beyond the customer's meter. The function of measurement and verification (M&V) is to independently and objectively protect the interest of all stakeholders by quantifying the DSM project impacts and their sustainability over the agreed contractual life of the DSM interventions. M&V provides the certainty that the reported savings are real and verifiable.

In India, as elsewhere, large scale investments in DSM resources have been hampered due to the inability of the project partners (electric utilities and energy service companies) to agree upon a method to measure and verify energy savings. Additionally, the concurrence of established protocols for M&V of savings, by the regulatory commissions is also significant to the sustainability of large scale DSM investments.

This document provides a review of the current M&V framework adopted in India and abroad. It further provides some of the best international practices and relevant case studies to illustrate successful M&V approaches and methods, which can guide Indian electric utilities in planning and acquiring megawatt scale DSM resources.

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1. Introduction

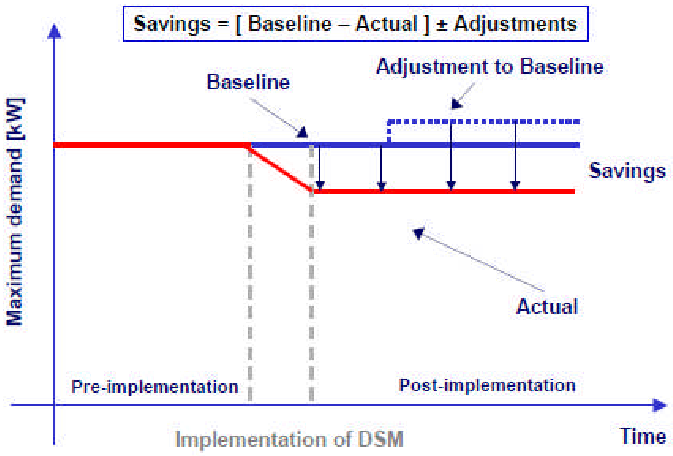
1.1. M&V: Meaning and purpose

"You can't manage or save what you can't measure (and verify)"

Demand side resources constitute the energy and demand savings resulting from the actions of a utility, beyond the customer's meter. The basis of a successful DSM resource acquisition rests on the fact that impacts can be determined to a degree of accuracy, trust and a cost that is acceptable to all stakeholders. This process is known as measurement and verification. The objectives of M&V are to provide an impartial, credible, transparent and a replicable process that can be used to quantify and assess the impact and sustainability of DSM programmes. The function of M&V is to independently and objectively protect the interest of all stakeholders by quantifying the DSM project impacts and their sustainability over the agreed contractual life of DSM interventions. M&V provides the certainty that the reported savings are real and verifiable, which is a necessity for electric utilities in a regulated environment. M&V activities include site surveys, metering of equipment, measurement, monitoring of energy and independent variables, engineering calculations, computing, reporting and evaluation[1]. How these activities are applied to determine energy savings depends on the characteristics of the DSM measures being implemented, the accuracy in energy savings estimates as well as the cost of conducting M&V.

1.2. General approach to M&V

Energy savings represent the absence of energy use. The Quantum of energy savings is generally determined by comparing the measured electricity consumption and demand after the implementation with what it was before the implementation. These pre-implementation electricity use conditions are described by a baseline. The baseline represents the electricity use linked to a set of conditions under which the system in question was operating prior to the implementation. The following diagram shows the fundamental approach to calculate savings through M&V by making appropriate adjustments for changes in baseline conditions:



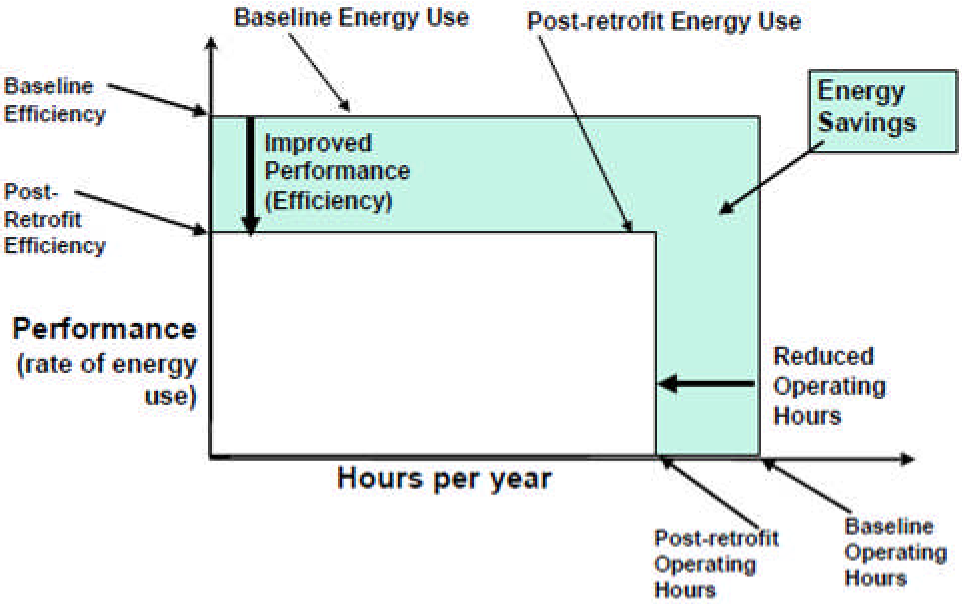
[1] The literature, policy, regulations and other documents generally use the terms monitoring, reporting, evaluation, measurement and verification in the same context for energy efficiency programs. To avoid ambiguity and confusion, this document will use the term **M&V,** which is an abbreviation for measurement and verification, for referring all activities used to determine or establish energy savings in DSM programs driven by utilities.

Factors driving the energy savings

The following are the factors that drive energy savings:

- Performance describes how much energy is used to accomplish a specific task;
- Usage describes how much of the task is required, such as the number of operating hours during which a piece of equipment operates.

Both performance and usage factors need to be known to determine savings. In the figure below, the area of the large box represents the total energy used in the baseline case. Reduction in the rate of energy use (increase in performance) or reductions in usage (decrease in operating hours) lead to reduced total energy use, which is represented by the smaller box. The difference between the two boxes, the shaded area, represents the energy savings.



1.3. M&V options

There are four options for M&V that have been derived from the International Performance Measurement and Verification Protocol (IPMVP). How one chooses and tailors a specific option is determined by the level of M&V rigour required to obtain the desired accuracy level in the savings determination. It is dependent on the complexity of the energy efficiency or the DSM measure, the potential for changes in performance, the measure's savings value, and the project's allocation of risk.

M&V options derived from the IPMVP[2]

Options	Performance and usage factors	Savings calculation
Option A: Retrofit isolation with key parameter measurement	This option is based on a combination of measured and estimated factors when variations in factors are not expected. Measurements are spot or short-term and are taken at the component or system level: both in the baseline and post-installation cases. Measurements should include the key performance parameter(s) which define the energy use. Savings are determined by means of engineering calculations of the baseline and post-installation	Direct measurements, estimated values and engineering calculations. Adjustments to models are not typically required.

[2] This table presents only three options. In our opinion, the fourth one suggests complex computer simulation models and is a derivative of the third one.

	energy use based on measured and estimated values.	
Option B: Retrofit isolation with all parameter measurement	This option is based on periodic or continuous measurements of energy use taken at the component or system level when variations in factors are expected. Energy or energy proxies are measured continuously. Periodic spot or short-term measurements may suffice when variations in factors are not expected. Savings are determined from an analysis of baseline and the reporting period energy use or proxies.	Direct measurements, engineering calculations and adjustments to models may be required.
Option C: Utility data analysis	This option is based on long-term, continuous, whole-building utility meter, facility level, or sub-meter energy (or water) data. Savings are determined from an analysis of the baseline and reporting period energy data. Typically, regression analysis is conducted to correlate with and adjust energy use to independent variables such as weather, but simple comparisons may also be used.	Based on the regression analysis of utility meter data to account for factors that drive energy use. Adjustments to models are typically required.

Steps to determine and verify energy savings

The following table shows the general steps involved in the process of M&V by utilities:

Before the programme implementation

- Step 1: Allocate program responsibilities
- Step 2: Develop a program specific M&V plan
- Step 3: Define the [redacted]

During the programme implementation

- Step 4: Roll out the program (incentives, rebates)
- Step 5: Conduct post-program ve[redacted] activities

After the programme implementation

- Step 6: Perform verification activities during the performance period at regular in[redacted]

1.4. Managing risks through M&V

In the context of M&V, the word 'risk' refers to the uncertainty that the expected savings will be realised, including the potential monetary consequences. This risk is usually derived from the usage and performance factors, which are not under the control of utilities. Risk related to usage stems from the uncertainty in operational factors such as weather, operational hours, equipment loads, user interventions etc. Performance risk is the uncertainty associated with characterising a specified level of equipment performance.

The usage risk is managed either by allowing the baseline adjustments based on measurements or by agreeing to the stipulated equipment operating hours, cooling load profiles, or other usage-related factors. Preventive maintenance, repair and replacement practices are adopted to manage the performance related risks.

Stipulating certain parameters in the M&V plan can provide cost effective ways to manage the risks. Using stipulations means that the utility, ESCO and the end users have agreed to employ a set value for a parameter throughout the term of the contract, regardless of the actual behavior of that parameter.

If no stipulated values are used and the savings are verified based entirely on measurements, then all risk resides with the ESCO and end users. This may not be cost effective and may lead to a reduced participation in the DSM programmes. Alternatively, the utility assumes the risk for the parameters that are stipulated. In the event that the stipulated values overstate the savings, or reductions in use decrease the savings, the utility must still pay the ESCO or the customer for the agreed-upon savings. However, if the actual savings are greater than expected, the utility may retain all of the surplus savings.

Therefore, the use of stipulations can be a practical, cost-effective way to reduce M&V costs and allocate risks. Stipulations used appropriately do not jeopardise the expected savings, the utility's ability to pay for the savings or the value of the project to the utility. However, stipulations shift risk to the utility and the utility should understand the potential consequences before accepting them. Risk is minimised and optimally allocated through carefully crafted M&V requirements including the diligent estimation of any stipulated values.

The allocation of responsibilities between the utilities, the customers or end users and the ESCOs drives the M&V strategy. This actually defines the specifics of how the savings will be determined. Completing the responsibility matrix serves as a useful exercise in understanding the approaches required for M&V because it indicates what factors are stipulated or measured and thus need to be documented during the life of the contract term. The allocation of responsibility must take into account the utility's resources, costs and preferences. In general, a contract objective may be to release the ESCO from the responsibility of the factors beyond its control; such as, pump set operation, weather and irrigated area. However, the ESCO should be held responsible for the controllable factors (risks), such as, maintenance of equipment efficiency.

Risk and responsibility matrix derived from usage and performance factors

Usage factors
• **Operating hours:** The utility generally has no control over the operating hours. Increases and decreases in operating hours can show up as increases or decreases in "savings" depending on the M&V method (eg, operating hours multiplied by the improved efficiency of equipment vs the utility bill analysis). **Clarify whether the operating hours are to be measured or stipulated and what the impact will be if they change.**
• **Load:** Equipment loads can change over time. The utility generally has no control over hours of operation, conditioned floor area, intensity of use (eg, changes in occupancy or the level of automation). Changes in load can show up as increases or decreases in 'savings' depending on the M&V method. **Clarify whether the equipment loads are to be measured or stipulated and what the impact will be if they change**.
• **Weather:** A number of energy efficiency measures are affected by weather, which neither the end user nor the utility has control over. **Clearly specify how weather corrections will be performed.**
• **User participation:** Many energy conservation measures require user participation to generate savings (eg, control settings). The savings can be variable and the utility may be unwilling to invest in these measures. **Clarify what degree of user participation is needed and utilise monitoring and training to mitigate risk.**
Performance factors
• **Equipment performance:** The contractor has control over the selection of equipment and is responsible for its proper installation, commissioning, and performance. The contractor has the responsibility to demonstrate that the new improvements meet the expected performance levels, including specified equipment capacity, standards of service, and efficiency. **Clarify who is responsible for initial as well as long-term performance, how it will be verified, and what will be done if performance does not meet expectations.**
• **Operations:** The day-to-day operations are negotiable and can impact performance. However, the contractor bears the ultimate risk regardless of which party performs the activity. **Clarify which party will perform equipment operations, the implications of equipment control, how changes in operating procedures will be handled and how proper operations will be assured.**
• **Preventive maintenance:** The day-to-day maintenance activities are negotiable and can impact performance. However, the contractor bears the ultimate risk regardless of which party performs the activity. **Clarify how long-term preventive maintenance will be assured, especially if the party responsible for long-term performance is not responsible for maintenance (eg, contractor provides maintenance checklist and reporting frequency). Clarify who is responsible for performing the long-term preventive maintenance to maintain**

operational performance throughout the contract term. Clarify what will be done if inadequate preventive maintenance impacts performance.
• **Equipment repair and replacement:** Performance of day-to-day repair and replacement of contractor-installed equipment is negotiable; however it is often tied to project performance. The contractor bears the ultimate risk regardless of which party performs the activity. **Clarify who is responsible for performing replacement of failed components or equipment replacement throughout the term of the contract. Specifically address potential impacts on performance due to equipment failure. Specify expected equipment life and warranties for all installed equipment. Discuss replacement responsibility when equipment life is shorter than the term of the contract.**

1.5. M&V issues and challenges in India

The business of electric utilities in India is regulated and, in the process of acquiring demand side resources, the electric utilities are mandated to measure and verify the energy and demand savings by way of regulations. Therefore, the perceived regulatory risk of demonstrating the energy and demand savings resulting from megawatt scale DSM investments is very high. The concurrence of established protocols for measurement and verification of savings, by regulatory commissions, is significant in terms of sustainability of the large scale DSM investments.

The high regulatory risk perceived by the Indian electric utilities has further hampered large scale investments in DSM resources by the inability of project partners (electric utilities and energy service companies) to agree on how the energy savings can be measured and verified.

The 'Model DSM Regulations' notified by the Forum of Regulators, in 2010, and various other DSM regulations notified by the state electricity regulatory commissions (SERC), indicate that the utilities shall carry out M&V activities as per the guidelines issued by the commission from time to time. However, there no guidelines on M&V currently available for the utilities in terms of planning and acquiring large scale DSM resources.

Regulatory provisions for M&V in the Indian DSM Regulations

Regulation	Relevant provisions
MERC Regulations on DSM Implementation Framework April 2010; **HPERC DSM Regulations, 2011**	✓ The distribution licensees shall be guided by the commission (evaluation, measurement and verification) regulations. ✓ Notwithstanding the above, till such time that such (EM&V) regulations come into force, the DSM programmes implemented by the distribution licensees shall be evaluated based on measurement and verification protocols submitted in the individual programmes or aggregated plans and validated by the DSM-CC. ✓ The commission may empanel independent verification contractors (IVC) to carry out the EM&V plans. ✓ The distribution licensees shall appoint the empanelled IVCs to carry out the EM&V plans. ✓ The commission may decide to carry out an EM&V activity for the individual programme(s) or entire plans by directly appointing empanelled IVCs.
GERC DSM Regulations, May 2012; **JKSERC DSM Regulations, 2011;** **OERC DSM Regulations, 2011;** **PSERC DSM Regulations, March 2012**	✓ The distribution licensee shall prepare plan for evaluation, measurement and verification of savings from DSM programmes as per the guidelines on EM&V issued by the commission from time to time. ✓ Third party EM&V of the DSM programmes may be undertaken by the commission or a third party assigned by the commission.
TNERC DSM Regulations, 2013	✓ The distribution licensee shall prepare a plan for the EM&V of savings from the DSM programmes; ✓ Third party EM&V of the DSM programmes may be undertaken by the commission or a third party

It is clear from the review of the various DSM regulations that the SERCs in India have committed to provide guidelines for the M&V activities of utilities while planning for the DSM programmes. However, the absence of such M&V guidelines in the current scenario can be construed as one of major barriers for up-scaling utility driven DSM investments in India.

2. International experience with M&V

Although M&V is an evolving science, the best industry practices have been developed internationally and these practices are documented in several guidelines.

The IPMVP is the first international guideline that has come to light. Currently in its fourth version, the IPMVP has been translated into 11 languages. The IPMVP was originally designed as a protocol to verify energy savings projects implemented by ESCOs under a shared savings type contract or a guaranteed savings contract. It has since found applications to a broad variety of energy and water conservation projects throughout the world.

ASHRAE Guideline 14 was developed subsequently in order to standardise the calculation of savings achieved by energy conservation measures (ECMs) and measures for reducing the energy demand. The M&V guidelines by the Federal Energy Management Program (FEMP) were developed to provide methods and specific guidance for the M&V of the energy savings achieved through an energy performance contract targeting a federal building.

***Spectrum of the international M&V guidelines for determining energy savings*[3]**

Context of utilisation	Description	Examples of M&V protocol or guidelines
Individual energy efficiency project M&V	Protocols or guidelines for evaluating energy savings for a single energy efficiency project implemented in an industrial enterprise or building (eg, a project implemented by an ESCO)	• IPMVP 2007 • ASHRAE Guideline 14: Measurement of Energy and Demand Savings 2002 • Federal Energy Management Program (FEMP) M&V Guidelines 2008 • Australasian Energy Performance Contracting Association: A Best Practice Guide to Measurement and Verification of Energy Savings
EE or the DSM programme evaluation	Protocols or guidelines for evaluating real energy savings generated by the EE or the DSM programmes. Different evaluation techniques may be used to demonstrate the savings achieved. Performing M&V on a sample of or all the projects included in the programme is one of them	• The California Evaluation Framework, 2004 • California Energy Efficiency Evaluation Protocol, 2006 • National Energy Efficiency Evaluation, M&V Standard, USA LBL • Model Energy Efficiency Programme Impact Evaluation Guide, US EPA • Energy Efficiency Programme Impact Evaluation Guide, U.S. Department of Energy (US DOE), SEE Action programme, 2012 • Eskom M&V Guidelines • American Electric Power M&V Guidelines • Xcel Energy M&V Guidelines • There are many other protocols and guidelines, published by investor owned utilities and public utility commissions in America that share similar basic concepts and principles, and are adapted to specific contexts of individual jurisdictions

The first utility driven DSM programmes in America were quite simple in design and consisted of awareness initiatives, distribution of energy efficiency devices or financial support for energy efficient equipment or energy audits. California was the first US state to prepare a formal evaluation protocol to evaluate the impact of DSM programmes in order to justify the ever larger sums invested year after year in programmes. California's current energy efficiency programme evaluation protocol is still being widely referenced and used by different utilities in the USA. Apart from the state of California, many investor-owned utilities and public utility commissions in

[3] Energy Efficiency Measurement and Verification Issues and Options, World Bank, July 2013

America have published M&V guidelines that share similar basic concepts and principles, and are adapted to specific contexts of individual jurisdictions.

In South Africa, Eskom, which is state owned electric utility, has rolled out several DSM programmes in the last decade to bridge the demand supply gaps in a cost effective and sustainable manner. The total value of DSM programmes funded through Eskom initiatives so far is around 5.6 billion INR. These investments are supported by detailed M&V guidelines, which are based on the IPMVP and are typically updated once a year. Standardised guidelines are developed and accepted for mature, well known and frequently sought technologies. Energy audit which is independently situated within the performance assurance section in the Eskom Assurance and Forensic department, is managing the M&V programme. The university M&V teams are contracted to do the actual M&V work and reporting thereon independently for energy audit.

The list of M&V guidelines available in South Africa for the utility driven DSM programmes is as follows:

- M&V Guideline
- M&V Standard Offer Guideline
- M&V Standard Product Guideline
- M&V Performance Contract Guideline
- M&V Pumping Guideline
- M&V Solar Water Heating Guideline (HP)
- M&V Solar Water Heating Guideline (LP)
- M&V Residential Load Management Guideline
- M&V Residential Heat Pump Rebate Guideline
- M&V CFL Guideline
- M&V CFL Methodology for Exchange Points Guideline
- M&V Geyser Insulation Guideline
- M&V Greenfield Guideline

Key lessons and recommendations for India

The existence of the M&V guidelines and protocols is critical to support and guide the efforts of utilities to invest in large scale DSM resources in a regulated environment.

The international M&V guidelines represent a library of collective experience that has evolved over the past 25 years to suit a diverse range of contexts, circumstances and situations. The IPMVP, especially, is rich in content and highly informative, and is a document that illustrates the most robust and sound principles for M&V and their scope and application are universal.

Drawing from the California experience, it is recommended that the Indian Forum of Regulators (FOR) view and use the IPMVP as a set of high-level references, for developing M&V principles for the Indian utility driven DSM market. The FOR may further use the California Energy Efficiency Evaluation Protocols and the Eskom M&V Guidelines to formulate and develop Indian M&V guidelines and protocols. Such guidelines developed by FOR should be specific to different programme designs, measures and technologies adopted by Indian utilities to acquire DSM resources. The FOR may also create a technical committee comprising of the Indian Bureau of Energy Efficiency (BEE), Energy Efficiency Services Limited (EESL), electricity distribution licensees, and other industry experts to develop and periodically update the envisaged guidelines.

In the following section, this paper presents some selective case studies and best practices to illustrate the M&V approach adopted for the selective DSM programmes.

3. Best practices

3.1. Agriculture DSM Pilot Project in Solapur, Maharashtra

The Maharashtra State Electricity Distribution Company Limited (MSEDCL) engaged CRI Pumps Private Limited (CRI) for the design, finance, and installation of 3530 energy-efficient agricultural pumps through ESCO performance contracting. The pump sets targeted to be replaced were located on five separate feeders in Solapur circle, Maharashtra. The terms of engagement involved that the CRI shall guarantee a certain level of savings to MSEDCL and recover the cost from the realised energy savings verified by a third-party contractor. The sharing of revenues resulting from the energy savings was pre-determined before the engagement process. The BEE appointed the third-party contractor for M&V of energy savings resulting from this project.

M&V approach

Option A: Retrofit isolation with key parameter measurement

The energy consumption of an agriculture pump set depends on multiple factors such as head, flow, efficiency, hours of operation, type and make of pump-set, farmer behaviour, the amount of land under irrigation, cropping patterns, water table declines (potentially affected by adjacent farmers), weather and rainfall. All these factors can affect the quantity of water pumped and the head, which will cause energy loads to vary, even if the technical performance of the ESCO's installed systems perform as specified. Variations in power quality can also affect pump performance, useful life and maintenance and replacement costs.

Monitoring all these parameters was perceived to be impossible given the constraints of implementing such programmes with farmers (particularly measurements involving electricity consumption) and was likely to be extremely expensive on account of the number of pumps of different types covering vast geographical areas having different underground water levels and effort and time envisaged.

For this reason, from the point of view of all stakeholders, **Option A** of IPMVP was chosen. Energy savings were determined by the following engineering formula:

$$\begin{aligned}&\boldsymbol{Energy\ savings}\\&\qquad = (\boldsymbol{Input\ power\ consumption\ of\ old\ pump}\\&\qquad - \boldsymbol{Input\ power\ consumption\ by\ new\ pump}) \times \boldsymbol{avg.operating\ hours}\end{aligned}$$

In the above mentioned formula, the input power consumption was measured for all the pump-sets before and after installation. To demonstrate the savings over the contractual term, periodic measurements were undertaken for a sample of pump-sets randomly chosen. The average annual operating hours were derived and agreed upon by the stakeholders before the engagement of CRI. Engineering calculations and computations were used to derive the annual average operating hours.

Dismantling existing pumps

The M&V scope in this project was not restricted to the establishment of energy savings. The third-party contractor was also engaged with the task of verifying the proposer disposal of the old inefficient pump-sets. In this regard, the third-party contractor verified that the CRI dismantled the existing pumps and kept an inventory of old pumps (with proper tagging of consumer ID), disposal of old pumps was undertaken in a manner that precludes their use or reinstallation in any form anywhere in India, photograph of old and new pump-set with consumer details were taken and the CRI had stored old pumps at their central warehouse.

3.2. Bachat Lamp Yojana

In this scheme, several DISCOMS in the country have entered into a tripartite agreement with BEE and BEE empanelled CFL suppliers to distribute CFLs at discounted prices to households. The business model of the BLY is based on the successful issuance of certified emission reductions (CERs) to each project. These CERs accrue each year to a project after it is verified that the use of the CFLs has resulted in the avoidance of CO_2 emissions due to the lower amount of electricity used by them as compared to the incandescent bulbs which they have replaced.

M&V approach

Option A: Retrofit isolation with key parameter measurement

Under the BLY projects, the BEE has been monitoring the CFL usage through the installation of GSM based smart meters in sample households in each project area of the country. The entire cost of monitoring in each project area is borne by the BEE under an approved scheme of Ministry of Power, government of India. The DISCOM will assist in selection of project sample group (PSG), and the project cross-check group (PCCG).The BEE will manage the monitoring of lighting appliance utilisation hours within the PSG households and undertake analysis of the monitored data.

As per AMS-II standards, monitoring consisted of monitoring either the ’power’ and ’operating hours’ or the ’energy use’ of the devices installed.

a) Recording the ’power’ of the device installed (e.g., lamp or refrigerator) using nameplate data or bench tests of a sample of the units installed and metering a sample of the units installed for monitoring their operating hours using runtime meters

OR

b) Metering the ’energy use’ of an appropriate sample of the devices installed

In the PSG, the BEE appointed third party will visit identified households and assess the following for each household:

i. Is the installed CFL in operation?
ii. If yes. install the GSM meter for monitoring (giving cross reference)

Subsequently for each household in the PSG, the BEE empanelled CFL supplier, who is eligible for the CERs will prepare a database with the following:

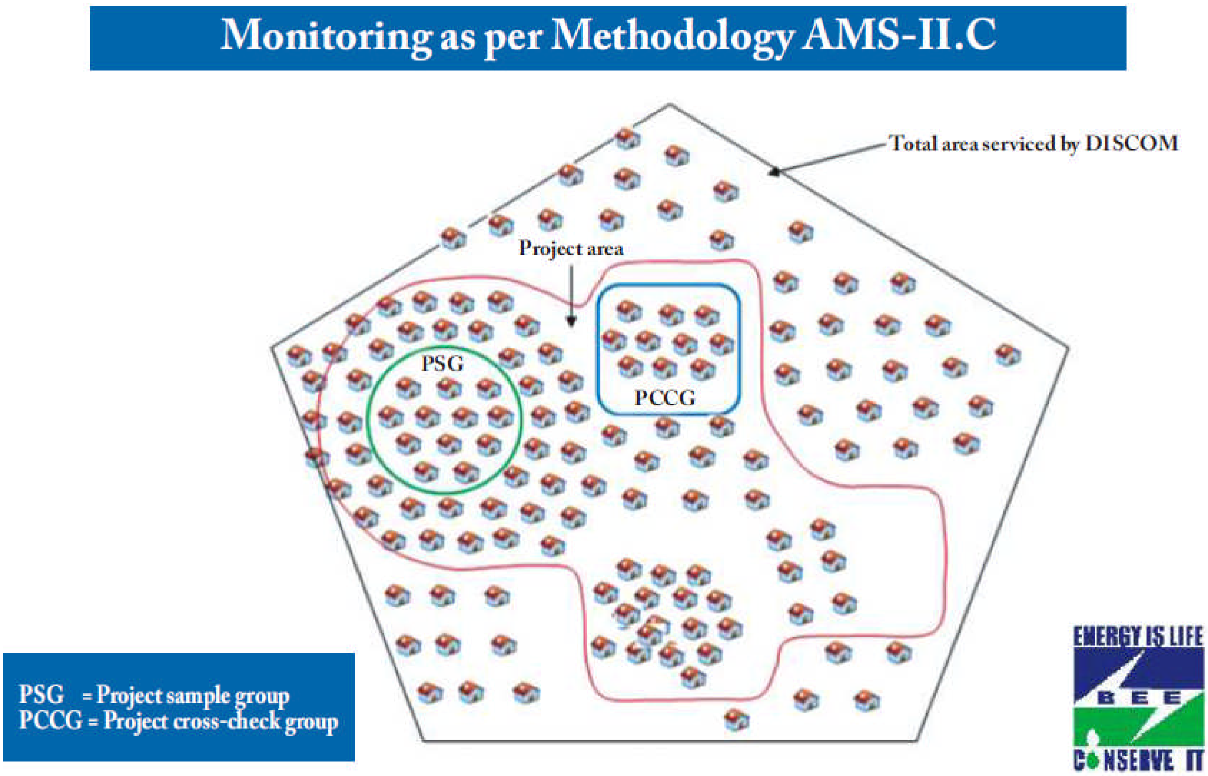
- A list of each household in the PSG (name, address, GPS location, and applicable area)
- Information on when the household has been added to the PSG and information on when it has been removed (if applicable)

For each CFL point, with the functioning monitoring equipment, the following monitored data will be collected and collated.

- Utilisation hours of the CFL
- Date of initial installation of the monitoring equipment and unique ID
- Calibration of the monitoring equipment
- Information on any changes made to the CFL and monitoring equipment (exchange, repair, removed and installed elsewhere, etc).

Apart from the data monitored in the PSG, spot checks are conducted periodically to cross-check the working condition of installed CFLs distributed at the time of the start of the project. The spot checks will be held every six months. With the assistance of DISCOM, the CFL supplier will undertake this task in the assigned area by selecting independent suitable agencies. The following data is collected during spot checks:

- A list of each household included in the spot check (name, address, unique identification e.g. GIS co-ordinates, etc, and applicable area).
- Number of the distributed CFLs in operation at the time when the spot check on the household is conducted
- Date of the spot check on the household

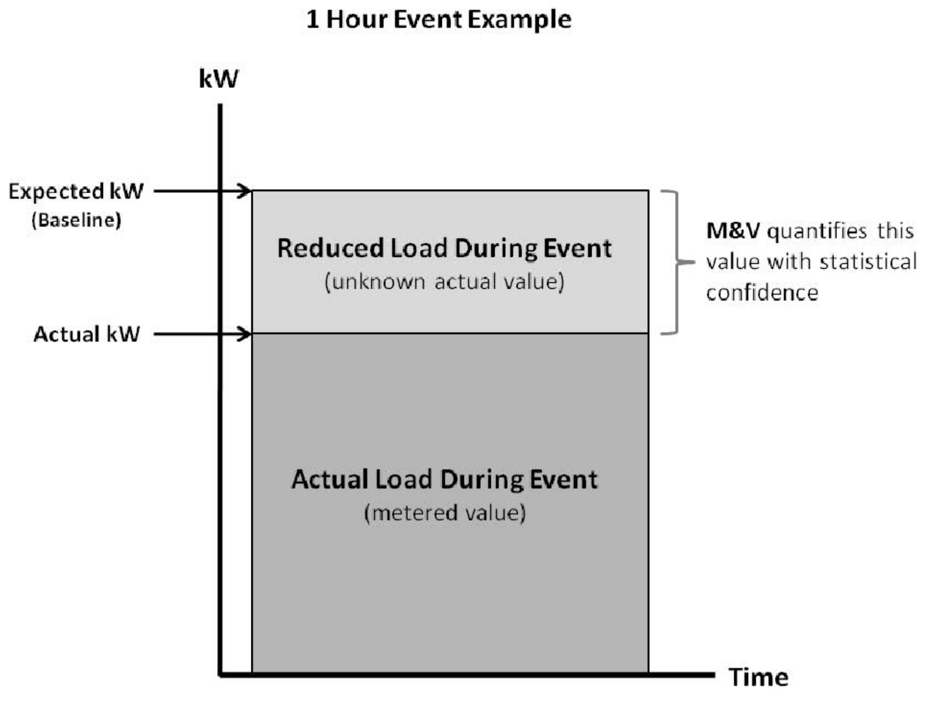


3.3. M&V for demand response programmes[4]

Demand response programmes sponsored by utilities incentivise changes in electric usage by end-use customers from their normal consumption patterns. The incentive payments are usually designed to induce lower electricity use at times of high wholesale power prices or when system reliability is jeopardised.

A **demand response event** is a period of time identified by the demand response programme sponsor (utility) when it is seeking reduced energy consumption and/or load from customers participating in the programme.

Depending on the type of programme and event (economic or emergency), customers are expected to respond or decide whether to respond to the call for reduced load and energy usage. The programme sponsor generally will notify the customer of the demand response event before the event begins, and when the event ends. Generally, each event is a certain number of hours, and the programme sponsors are limited to a maximum number of events per year.



Source: DR M&V, AEIC, 2009

Measurement quantifies the load reduction during demand response events and verification provides evidence that the reduction is reliable.

Baseline will be the amount of energy the customer would have consumed in the absence of event. This hourly usage curve is created using different engineering methodologies.

Actual usage is the amount of energy the customer actually consumed during the DR event period. This is usually determined from AMR meters which record energy and demand parameters at 15-minute intervals.

Load reduction is simply the mathematical difference between the baseline and the actual use.

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[4] Demand response programmes can be automated using smart meters and other IT infrastructure. The M&V approach discussed in this section is redundant to such programmes as all key parameters are monitored real time. This approach is useful only to such programmes which are based on aggregators who enter into agreements with a specific group of customers and coordinate the entire event with the DISCOM.

Baseline – actual use ± adjustments = load reduction

The calculation of the baseline is a critical piece of these particular programmes. If the baseline for a customer is calculated too high, the electric utility will pay incentives in excess of the customer response. If the baseline is too low, less or no load reduction will be recorded leading to customer non-participation in future DR events. It may also eliminate incentives to participate, resulting in a customer requesting to be removed from the demand response programme. Therefore, it is in the best interest of both the utilities and the customers to have as accurate a baseline estimation as possible.

Baseline calculation methodology

Proxy day matching is the simplest approach to estimate baseline for DR events and its attempts to select a baseline day that most accurately matches the DR event day.

Day matching consists of taking a short historical time period (which can be anywhere from one week to 60 days in length) and attempting to match what the usage for an event day would have been based on the usage during the historical period chosen. This usually involves choosing a subset of days from the historical period and averaging them, often with an adjustment for the current day's conditions applied to the calculated baseline.

For example, if the DR event day occurs on a weekday, hourly data from weekdays are used in the calculation of the baseline. The small subset of days and the historical days are the same type of day as the DR event day such as a weekday or weekend. This results in a baseline load curve of average hourly values calculated from a customer's previous actual use. In the figure alongside, three equivalent days prior to the DR event day are selected to be averaged together to create a baseline.

Hour	Days Averaged to Create Baseline			Hourly Baseline
	Day 1	Day 2	Day 3	
1	1.81	1.20	1.14	**1.38**
2	1.64	1.08	0.98	**1.23**
3	1.49	0.97	0.92	**1.13**
4	1.41	0.91	0.88	**1.07**
5	1.34	0.93	0.83	**1.03**
6	1.30	0.96	0.83	**1.03**
7	1.29	1.02	0.89	**1.07**
8	1.45	1.05	1.04	**1.18**
9	1.53	1.10	0.99	**1.21**
10	1.59	1.31	1.09	**1.33**
11	1.75	1.52	1.10	**1.46**
12	1.86	1.58	1.14	**1.52**
13	2.06	1.83	1.23	**1.71**
14	2.11	1.98	1.39	**1.83**
15	2.21	2.16	1.47	**1.95**
16	2.29	2.22	1.62	**2.04**
17	2.30	2.25	1.76	**2.11**
18	2.41	2.37	1.75	**2.17**
19	2.41	2.43	1.89	**2.24**
20	2.29	2.24	1.75	**2.09**
21	2.26	2.24	1.71	**2.07**
22	2.37	2.34	1.71	**2.14**
23	2.27	2.24	1.65	**2.05**
24	1.99	1.88	1.45	**1.77**

Hourly baseline = Average of Day 1, Day 2, Day 3

Another approach uses daily energy (the sum of the 24-hourly energy values for a day) to choose which days are included in baseline calculation. Suitable days are selected based on their daily energy being comparable (75% or greater) to the daily energy of a selected day, prior to the DR event day. A daily energy ratio is calculated (see table alongside) by comparing the daily energy of the suitable days to the daily energy of the selected day prior to the DR event.

Average daily energy usage approach example

Date	Day of week	Daily energy	Ratio	Acceptable day
31 July 2012	Tuesday	39.899	1.307	Yes
25 July 2012	Wednesday	40.264	1.323	Yes
20 July 2012	Friday	29.899	0.982	Yes
16 July 2012	Monday	28.995	0.952	Yes

Baseline adjustment

An adjustment to the calculated baseline might be needed to factor in the weather effects on a customer's load on the DR event day. This adjustment consists of determining the difference between the calculated baseline and the actual customer load during the DR event hours. The adjustment value is mathematically determined and applied to the calculated baseline during the hours of the deployment period of the DR event.

4. References

1. http://mnv.lbl.gov/
2. M&V Guidelines: Measurement and Verification for Federal Energy Projects, Version 3, Office of EERE, U.S. Department of Energy, Federal Energy Management Programme, 2008
3. A Best Practice Guide to Measurement and Verification of Energy Savings, The Australasian Energy Performance Contracting Association, 2004
4. Energy Efficiency Measurement and Verification Issues and Options: An Overview of International Measurement and Verification Experience; World Bank 2013
5. http://www.eskom.co.za/IDM/MeasurementVerification/Pages/Measurement_Verification.aspx
6. http://www.beeindia.in/
7. Demand Response Measurement and Verification, AEIC Load Research Committee, 2009

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