

## BOMA Toronto CDM Program Measurement and Verification: Industry Practice and Principles

Savings cannot be directly measured...only calculated.

### Savings = Baseline Energy Use – Post Retrofit Energy Use

The challenge is to balance M&V costs, savings certainty, and the value of the conservation measure.

*Four generic M&V options can be employed:*

- A. Engineering calculations (using both stipulated values and measurements)
- B. Metering and monitoring (spot, short term, or continuous measurements)
- C. Utility bill analysis
- D. Computer simulation models.

*Considerations in selecting the M&V option include:*

- Complexity of the measure
- Potential for changes in key factors that affect the baseline and post retrofit conditions
- The measure's savings value
- The measure's cost and program incentive level

**Option A** and **B** are applied at the *measure* or *system* level.

**Option C** is applied at the *whole building* level.

**Option D** is applied at either the *whole building* or *measure* level.

When M&V is applied at the *measure* the primary considerations are:

1. Is the load constant (e.g. lighting fixture) or variable (e.g. VSD applied to a fan).
2. Are the operating hours constant (e.g. garage lighting) or variable (e.g. cooling hours)

Spot measurements can suffice for constant loads, whereas short term or continuous measurements may be required for variable load.

Where operating hours are constant, stipulated values can be applied, subject to validation. Where operating hours are variable, short term or continuous measurement may be required.

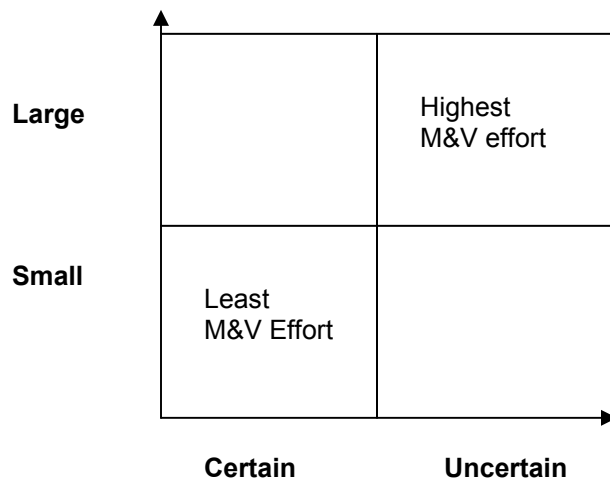
## **Measurement and Verification (M&V) – General Principles to be applied under the BOMA CDM Program**

BOMA’s Agreement with the Ontario Power Authority stipulates that the criteria used in evaluating projects for energy and demand reductions “shall be consistent with IPMVP Protocols”.

IPMVP Protocols means the International Performance Measurement & Verification Protocol (IPMVP) Volume 1 – Concepts and Options for Determining Energy and Water Savings as in effect from time to time. See [www.evo-world.org](http://www.evo-world.org)

As it relates to projects being evaluated under the BOMA CDM Program:

- M&V will be applied at the *measure* level only. No interactive savings effects are considered. This simplifies M&V efforts to a large extent, and limits the options to consider.
- Only Options A and B will normally be employed – i.e. using a combination of stipulated values (referenced to industry standards or agreed site operating conditions), spot and short-term measurements.
- M&V will ensure diligence in establishing the baseline conditions and in defining the requirements for confirmation of post-retrofit savings.
- M&V efforts will vary according to:
  - Savings size (projected savings and potential incentive)
  - Savings uncertainty (doubt about likely result of the measure’s activity)



- Measures that attract the *kW Demand Savings incentive* will generally have greater M&V rigor applied than measures attracting only the *kWh energy savings incentive*.
- kW Demand Savings are determined over a one hour period, as occurring on business days during the hours of 7am to 8 pm, June through September. For measures that are weather dependent, kW savings shall be considered as occurring at peak design load conditions.
- All measures will be required to report kWh savings. However the determination of kWh savings will be of secondary importance for measures that attract a kW Demand Saving incentive.
- For ‘small’ and ‘certain’ projects, ‘least M&V effort’ will involve acceptance of stipulated kW or kWh values, subject to reasonableness and validity checks, relative to industry norms.
- For ‘large’ and ‘uncertain’ projects, the ‘highest M&V effort’ will involve more rigorous scrutiny of baseline conditions specific to the facility, involving spot or short term measurements on all, or a representative sample, of loads or operating hours as applicable.
- Baseline and post-retrofit conditions will be confirmed through physical audits/inspections for all projects claiming significant incentives. Projects with less than 25kW or less than 225,000 kWh of projected savings may be subject to simplified evaluation processes.

- Extended post retrofit monitoring is not generally contemplated. (Extended monitoring may be done for other purposes, but will not be a condition of incentive payment, except if it is a specific condition of the accepted M&V plan for a particular project.)
- Where available, existing data, as obtained through sub-metering, BAS logs, etc., will be utilized to the fullest extent, and will be considered as greatly enhancing the quality of the M&V.
- Enhanced M&V efforts undertaken by the Participant, including the use of existing monitoring data, can be used to support savings claims (subject to acceptability of the data quality).
- Measures with a high degree of savings uncertainty will be conservatively discounted with an option (and onus) for Program Participants to prove greater savings through extended pre and/or post-retrofit monitoring.
- M&V Procedures are subject to continuous improvement, consistent with the principles described here, as program experience and empirical data are gained.

## M&V Procedures by Eligible Measure

The following table lists the M&V Procedures to be applied according to:

- Type of Measure
- '*Basic*' or '*Enhanced*' M&V

Generally,

'**Basic**' M&V will be considered for measures with less than 50 kW or 400,000 kWh/yr savings

'**Enhanced**' M&V will be considered for measures with greater than 50 kW or 400,000 kWh/yr savings

Measure Type	M&V Procedure	
	'Basic'	'Enhanced'
Lighting Retrofit	LR-B	LR-E
Equipment Replacement	ER- B	ER-E
HVAC Re-Design		HVAC-E
Variable Speed Drives (VSDs)	VSD-B	VSD-E
Building Envelope	BE-B	BE-E
Building Automation Systems (BAS)	BAS-B	BAS-E
Lighting Controls	LC-B	LC-E
Sub Metering		SM-E
Deep Lake Water Cooling		DLWC-E
Ground Source Heat Pumps		GSHP-E
Other Custom Measures		OCM-E
Power Conditioning Devices		PCD-E
Elevator Retrofit	ELR-E	ELR-E
Elevator Control	ELC-E	ELC-E

## 1. Lighting Retrofit

- Likely to claim \$/kW.
- Load is constant when operating
- Stipulation of operating hours is acceptable, subject to validity checks.
- Same procedure applies to both kW and kWh incentive measures.

### LR-B: 'Basic' M&V:

- Baseline wattage established from industry references to the various lamp/ballast types installed.
- Post-retrofit wattage is to be established from manufacturer's data sheets (to be provided with application) and/or industry references.

### LR- E: 'Enhanced' M&V:

- Provide same information as LR-B, plus
- Spot measurement RMS wattage readings for a minimum of 6 randomly selected fixtures of each type of lamp/ballast combination for both Baseline and Post-Retrofit conditions.
- Post retrofit measurements must allow for min. 100 hours of burn-in
- (Note: Applicants must be prepared to demonstrate wattage readings during site inspections by the Project Evaluator).

NOTE: Both LR-B and LR-E require the Participant to provide detailed site surveys that include:

- Inventory of lamp/ballast fixture type by area
- Usage area designation and operating periods (e.g. common space 7x24; tenant space – lease hours).
- Counts of operating and non-operating fixtures and lamps

Where there are different lamp types being employed in a given fixture, the default baseline condition will generally be the lowest wattage value.

## 2. Equipment Replacement: Chillers, Motors, Refrigeration

- Claim \$/kW or \$/kWh.
- Whether load is constant or variable, refer to manufacturers' data, industry references, for kW ratings at various load points.
- Assumptions for operating profile, both load and hours, to be reviewed for reasonableness.
- Provide detailed inventory of all equipment, baseline and proposed post-retrofit, showing quantities, thermal and electrical ratings.

### ER – B: 'Basic' M&V

Chillers and Refrigeration:

- kW savings - stipulated values, at 80% of nameplate capacity of operating equipment, of baseline and post-retrofit kW, Baseline kW shall assume OEM rated or shop tested efficiency.
- kWh savings – stipulated values for baseline and post-retrofit kW at representative distributed load levels spanning total capacity, multiplied by stipulated hours at each point.
- Exclude chiller auxiliary equipment (pumps and cooling tower) unless this equipment is changed as well

## Motors:

- kW savings - stipulated values for efficiency and power factor, at 80% load, using manufacturer ratings.
- kWh savings = kW savings x stipulated hours
- if variable load, stipulate efficiency and power factor at representative load levels, and stipulate hours at each level.

## ER – E: ‘Enhanced’ M&V

### Chillers and Refrigeration:

- kW savings - Baseline and post retrofit performance is to be measured at current peak design load. This is to reflect design load for the facility, not 100% capacity of the equipment. Measurements are to be made at three different times and averaged. Measurements may be normalized to design temperature conditions. If equipment capacity is to be changed, apply the baseline tonnage for both measurements. If Amperage measurements are used they must be referenced to manufacturers’ performance data sheets showing amps vs. tonnage load.

In the absence of measured performance data the default assumption will be 60% of nameplate rated load.

- kWh savings – Baseline and post retrofit performance is to be measured at representative distributed load levels spanning total design loads, multiplied by stipulated hours at each point.

### Motors :

- kW savings – spot or short term measurements of kW input and power factor.
- kWh savings = kW savings x stipulated hours
- if variable load, measure kW input and power factor at representative load levels, and stipulate hours at each level.
- Measurements shall be made on not less than 20% of a sample population and load of comparable equipment.

### 3. HVAC Redesigns (all require 'Enhanced' M&V)

#### HVAC – E: 'Enhanced' M&V

- Could claim either \$/kW or \$/kWh
- Review of baseline conditions, including short-term measurement, reference to engineering estimates.
- Engineering review and validation of proposed changes, subject to spot or short-term measurement for post-retrofit conditions.
- Provide proposed M&V plan, consistent with IPMVP protocols.
- Component measures within the HVAC Re-design are to be considered separately and in isolation, to the extent practical.

### 4. Variable Speed Drives (VSDs)

- Likely to claim \$/kWh
- Load is likely constant for baseline, variable (by definition) post retrofit.
- Refer to manufacturers' data, industry references, for kW ratings at various load points.

#### VSD – B: 'Basic' M&V

- Stipulate baseline motor efficiency and power factor if baseline is constant; stipulate efficiency and power factor at representative load levels if baseline is variable; stipulate hours at each level.
- Assumptions of operating profile both load and hours, will be reviewed for reasonableness.

#### VSD – E 'Enhanced' M&V

- Spot or short-term measurements to establish operating load profile for baseline and post-retrofit conditions.
- Participant should ensure comparable operating conditions for both baseline and post-retrofit measurements.
- Measurements shall be made on not less than 10% of a sample population and load of comparable equipment and operating profiles.

## 5. Building Envelope

- May claim either \$/kW or \$/kWh.
- Involves consideration of cooling efficiency in assessing summer savings.
- Refer to manufacturers' data, industry references, for thermal or leakage properties.

### BE – B: 'Basic' M&V

- Stipulated values for cooling kW/ton
- Stipulated values, derived from detailed simulation modeling provided by the manufacturer of the installed product for typical buildings. The model shall account for actual glazing types, , and actual building envelope features, shading, orientation and normal local weather. The model shall be adjusted to the specific site conditions.

### BE- E: 'Enhanced' M&V

- Refer to ER- E for determination of cooling kW/ton
- Use hour-by-hour annual whole building energy simulation model for kWh savings, calibrated against whole building metered data for electricity used in the building. (Peak month only for kW). Simulations should demonstrate solar effects and coincident loading for all orientations.
- Detailed models as provided by manufacturers or by the Applicant that account for glazing types and orientation are acceptable in the absence of simulation models for the specific facility.
- Blower door tests are required to demonstrate infiltration reduction

## 6. Building Automation System (BAS)

- Likely to claim \$/kWh.
- Recognized as inherently uncertain.
- May be a new BAS installation or an enhancement of an existing system.

### BAS – B: 'Basic'

- Provide detailed description of baseline and post-retrofit operating conditions, with anticipated savings.
- Provide operating logs or other monitoring data to support claimed operating conditions.
- Discount savings that have supporting baseline data by 25%
- Discount savings that have no supporting baseline data by 50%

## BAS – E: ‘Enhanced’

- Spot or short-term measurements, during the summer season, to substantiate operating profile and set points (baseline and post-retrofit) in a sample of loads.
- Discount savings that can be spot tested by 25%
- Discount savings that cannot be spot tested by 50%

## 7. Lighting Controls

- Likely to claim \$/kWh.
- Recognized as inherently uncertain.
- May be a new installation or an enhancement of an existing system.

## LC – B: ‘Basic’ M&V

- Provide detailed description of baseline and post-retrofit operating conditions, with anticipated savings.
- Provide operating logs or other monitoring data to support claimed operating conditions.
- Discount savings that have supporting baseline data by 25%
- Discount savings that have no supporting baseline data by 50%

## LC – E: ‘Enhanced’ M&V

- Spot or short-term measurements, during the summer season, to substantiate operating profile and set points (baseline and post-retrofit) in a sample of loads representing not less than 10% of similar circuits.
- Discount savings that can be spot tested by 25%
- Discount savings that cannot be spot tested by 50%

## 8. Tenant Sub-Metering

- Likely to claim \$/kWh.
- Recognized as inherently uncertain.
- Note that there is only one M&V procedure ('Enhanced') that applies to all projects regardless of size. This differs from other measures in that an initial incentive payment is determined following implementation, with opportunity for additional incentives based on subsequent results achieved.

Savings will be determined according to metered tenant load that is subsequently cost allocated as a result of sub-meter installation. Unoccupied floor space shall not be considered.

### SM – E: 'Enhanced' M&V

Provide detailed description of:

- Loads that are proposed to be sub metered
- Details of the tenant billing procedure.
- Description of planned tenant education and engagement activities to support the reduction of discretionary tenant energy usage.
- Preliminary estimate of metered tenant load, including assumptions.
- Actual metered tenant load shall be determined from measurements of at least one month duration following implementation. The initial incentive payment will be based on 5% of this value.

Following an implementation period of not less than 6 months, provide:

- Description of tenant engagement experience and supporting metering of tenant usage over the period.
- A calculation of savings, based on the minimum 6 month engagement period, properly reconciling for vacant space and material changes to energy consuming equipment.
- The incremental payment will be made based on the difference between the post 6-month calculations of savings less the initial 5% payment. There will be no claw back of the initial 5% payment. Discount of incremental savings will be from 0-50% depending on the duration of measurement and quality of data and presentation.

## 9. Deep Lake Water Cooling (all require 'Enhanced' M&V)

- Likely to claim \$/kW.

### DLWC – E: 'Enhanced' M&V

- Rigorous review of existing chiller operations, including peripherals (cooling tower, condenser pumps): kW/ton, peak loading, equivalent run-hours. Reference to industry norms, manufacturer's data, and sub-metering data where available. Utilize billing data and interval data for validation where possible.
- Savings will be discounted by a stipulated value (provided by BOMA) to account for energy requirements in the delivery of DLWC.
- Option to use actual measured tons and ton-hours post retrofit to confirm final savings.

## 10. Ground Source Heat Pumps (all require 'Enhanced' M&V)

- May only claim on the basis of \$250 per ton of installed cooling capacity. (This is to be consistent with other OPA programs that specifically support the implementation of ground source heat pumps as a renewable energy application.)

### GSHP – E: 'Enhanced' M&V

- Provide details of existing cooling plant operations, and (if applicable) existing electric heat operations. – system type, capacities.
- Provide load calculations as applicable to support the selection of ground source heat equipment.
- Provide equipment details regarding the new ground source heat pump equipment and expected operation, specifically including the installed tons of cooling capacity.

## 11. Other Custom Measures. (all require 'Enhanced' M&V)

OCM – E: 'Enhanced' M&V

M&V for other Custom measures must adhere to the principles described in IPMVP Volume 1, 2002 or later. M&V should also be consistent with the principles described here as applying to the BOMA CDM Program and consistent with measure specific M&V procedures as described here, to the extent applicable.

## 12. Power Conditioning Devices (all require 'Enhanced M&V')

PCD – E: 'Enhanced M&V

This procedure addresses the application of power conditioning devices that are connected either directly at end-use equipment or at a distribution panel or service entrance serving multiple end use loads and/or circuits.

Power conditioning devices are employed to provide operational benefits and cost savings through techniques such as voltage regulation, power factor correction, reduction of harmonic content, and elimination of electrical transients.

While tangible operational benefits can result from employing such devices, it must be noted that the BOMA CDM Program only provides incentives for quantifiable energy reductions and/or peak demand reductions measured as real power (kW) or energy (kWh). To confirm, savings in reactive power (kVar) or apparent power (kVA) are not eligible for incentives.

Savings attributable to the application of power conditioning equipment are considered to be specific to the end use equipment and its operating characteristics, and the local electrical environment.

An ideal M&V approach is to assess the energy usage of given end-use equipment, both with and without the application of the power conditioning device, under identical operating conditions.

In practice, comparing under identical operating conditions may not be practical due to normal variations in equipment loading and electrical supply conditions.

Recognizing this inherent variability, the M&V procedure for Power Conditioning Devices is designed to minimize the effects of variability by employing successive measurements with the power conditioning device activated and not activated ( i.e. 'On-Off') over a period of time.

Specific procedures are as follows:

- Measurements of real power (kW) shall be taken with a three-phase power analyzer capable of recording at a minimum of 128 samples per cycle, and calibrated to within +/- 1% of reading accuracy.
- Measurements shall be taken on the load that is subject to the application of the power conditioning device under typical operating conditions, with a minimum of expected variability.
- Measurements shall be recorded for successive 15 minute intervals of the power conditioning device being activated and not activated. These recordings shall occur over a period of a minimum of 4 hours duration, over which time there shall be a minimum of 8 fifteen minute periods of the power conditioning device being both activated and not activated.
- Energy (kWh) savings for the measurement period shall be assessed as the difference between the cumulative recorded energy in each of the 'on' and 'off' intervals. Annual energy savings shall be considered as the % energy savings during the measurement period multiplied by the annual consumption of the measured circuit/application. Annual consumption can be estimated by extrapolating from recorded energy usage of minimum 1 week duration.
- Demand (kW) savings, if they are to be considered, shall be assessed as the difference in average demand in each of the 'on' and 'off' recorded intervals. Average demand is to be calculated as total cumulative energy in kWh divided by total hours for intervals in which the power conditioning device is activated, and not activated, respectively. Note that for demand savings to be considered the measurements shall be taken during the peak period (between 7am and 7pm weekdays) and the application must be considered to be operating routinely during such peak times.
- Where multiple Power Conditioning Devices are employed the sample size for measurement shall be 20% of the equipment operating under like conditions.

Savings shall not be extrapolated to alternate operating conditions without measurement under such conditions.

## 13. Elevator - Retrofit (Motors & VSD)

- Likely to claim \$/kW or \$/kWh
- kW savings - stipulated values for efficiency and power factor, at 80% load, using manufacturer ratings.
- kWh savings = kW savings x stipulated hours
- Load is likely constant for baseline, variable (by definition) post retrofit.
- if variable load, stipulate efficiency and power factor at representative load levels, and stipulate hours at each level.

Refer to manufacturers' data, industry references, for kW ratings at various load points

### ELR – E: 'Enhanced'

Elevator modifications (where only variable speed drives are added or elevator motors are replaced), are classified as Elevator Retrofit (ELR), and should follow VSD or ER methods, respectively.

In addition to the requirements of VSD or ER methods:

- For Basic methods (<50 kW or <400,000 kWh/yr), the kW savings shall be computed to reasonably reflect the likely elevator operating profile during peak day time hours.
- For Enhanced methods, continuously record the electricity use of all affected equipment for duration sufficient to establish an operating profile, minimum of 24 hours, for both baseline and retrofit conditions. Provide evidence that building occupancy was similar for the two test periods, and how they might be different for normal summer occupancy. Recordings shall show power draw averaged over one hour intervals. These recordings shall be used:
  - for kW calculations, to determine the measured electrical demand that occurs during typical summer peak periods on the associated utility meter; and
  - for kWh calculations, to support the stipulation of annual motor operating hours for each representative load level, with due consideration of operating profile during off peak periods.

## 14. Elevator - Controls

- Likely to claim \$/kW or \$/kWh
- kW savings - stipulated values for efficiency and power factor, at 80% load, using manufacturer ratings.
- kWh savings = kW savings x stipulated hours

All other types of elevator modifications, including elevator replacement, are classed as Elevator Controls (ELC), and recognized as inherently uncertain. Due to the variability in elevator usage and the lack of established information on which to base assumed usage profiles, no Basic method is available.

ELC – E: ‘Enhanced’ (for all sizes of elevator control projects)

- Describe the normal weekly elevator usage profile, and the baseline and post-retrofit control logic.
- Continuously record the electrical load of all affected equipment for one week that is representative of normal operation, under both baseline and retrofit conditions. Where multiple, identical elevators exist measurements shall be made on not less than 10% of the sample population. Electrical recordings shall show power draw averaged over one hour intervals. These recordings shall be used:
  - to determine the kW impact of the retrofit during peak daytime hours.; and
  - to determine the weekly change in total kWh, which must then be adjusted for any changes in relevant occupancy conditions, and projected to annual kWh savings.
- For the period of the electrical logs, provide information to demonstrate that occupancy was normal or at least the same during the two periods. Also provide logs to show that the baseline and control logic remained in place throughout the respective periods.