This paper presents cost effective methods for M & V (Measurements and Verification) of energy savings achieved through implementation of HVAC energy efficiency projects. The proposed M & V Plan is based on IPMVP (International Performance, Measurement and Verification Protocol) and the use of suitably qualified professional certified energy management engineers – CMVP (Certified Measurement and Verification Professional).

It provides better understanding on what are engineering challenges to design the most cost effective sub-metering system as part of M & V Plan, within the given four M & V generic options (IPMVP – Options A, B, C & D).

Emphasis of the paper is to highlight the key M & V design concepts that ensure optimal number of sub-meters at suitable locations, as well as basic requirements for processing, diagnostics and reporting of the collected data.

The paper also analyses one case study that fully demonstrates DOs and DON'Ts of how to prepare M & V plan, how to ensure smooth implementation and transparent ongoing monitoring and verification of achieved savings of implemented HVAC energy efficiency.

Normalisation of actual weather data (BOM – Bureau of Meteorology), as part of M & V Plan, for a given location and a given period of time, is demonstrated via regression analysis, using correlation between actual CDD, HDD (Cooling/Heating Degree Days) and actual energy consumption data.

Creation of cost effective sub-metering, as part of M & V Plan, include use of VSD (Variable Speed Drive) controllers with HLI (High Level Interface) as sub-meters with sufficient accuracy for M & V purpose, as well as use of temporary data loggers.

The paper also addresses an issue of the current M & V practices where many BMS companies up-sell sub-metering arrangements that are not based on the
best M & V engineering practices (IPMVP) and in many cases do not represent good value for money for clients.

The paper also explains how proper M & V plan can reduce capital costs of implementation of HVAC projects in Australia, via creation and sale of Energy Saving Certificates.

**Key words:** M & V, CMVP, IPMVP, Energy Efficiency, Energy Management

**Introduction**

Metering or tracking energy use has traditionally been accomplished by minimal number of utility meters (in the most of cases just one), in order to minimise cost of metering.

This type of metering however, does not provide information on energy use at points of use (where, when and how much energy was consumed by different building services – lighting, air conditioning, vertical transportation, etc).

Sustainable energy and energy reduction goals are driving the need for better understanding of energy use by the end users. With energy prices rising and budget tightening, energy efficiency upgrades has become increasingly important as the most cost effective mean to reduce energy consumption of building services.

Capturing this low hanging fruit starts with metering and sub-metering (lower levels and sub-levels of metering, compared to utility metering), which provides a backbone of knowledge about where resources are being used and energy saving potential.

**Sub-metering and M & V plan**

Measurement and Verification (M & V), according to IPMVP (International Performance, Measurements and Verification Protocol – written by Efficiency Valuation Organisation - EVO) is the process of using measurements (including metering and sub-metering) to reliably determine actual energy savings.

An adequate M & V Plan is essential to economically justify introduction of sub-metering, before the level of energy saving is known.

EVO runs worldwide trainings and exams for obtaining M & V certification - CMVP (Certified Measurement & Verification Professional) to ensure a minimum quality for writing proper M & V plans for different facilities and energy systems.

It is clear that meters, on their own, do not save energy and money, but cost money to purchase and install. That’s why the key to maximising energy saving is to complement sub-metering system with appropriate procedures:

- Collect the data
- Keep records
- Analyse the data
- Take Action

The main roles of M & V include:

- Verify utility bills
- Allocate energy costs & assign accountabilities
• Determine equipment and system efficiencies
• Identify equipment and process problems
• Identify energy saving opportunities

M & V has to be:

• Accurate
• Complete
• Conservative
• Consistent
• Relevant
• Transparent
• Cost effective
• Suitable to the readers level of understanding

Energy Saving quantification (IPMVP)

IPMVP prescribes four options to quantify energy savings:

• Option A (Retrofit Isolation: Key Parameter Measurement)
• Option B (Retrofit Isolation: All Parameter Measurement)
• Option C (Whole Facility)
• Option D (Calibrated Simulation)

<table>
<thead>
<tr>
<th>ECM Project Characteristic</th>
<th>Suggested Option</th>
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<tbody>
<tr>
<td>Need to assess ECMS individually</td>
<td>A</td>
</tr>
<tr>
<td>Need to assess only total facility performance</td>
<td>X</td>
</tr>
<tr>
<td>Expected savings less than 10% of utility meter</td>
<td>X</td>
</tr>
<tr>
<td>Significance of some energy driving variables is unclear</td>
<td>X</td>
</tr>
<tr>
<td>Interactive effects of ECM are significant or unmeasurable</td>
<td>X</td>
</tr>
<tr>
<td>Many future changes expected within measurement boundary</td>
<td>X</td>
</tr>
<tr>
<td>Long term performance assessment needed</td>
<td>X</td>
</tr>
<tr>
<td>Baseline data not available</td>
<td></td>
</tr>
<tr>
<td>Non-technical persons must understand reports</td>
<td>X</td>
</tr>
<tr>
<td>Motoring skill available</td>
<td>X</td>
</tr>
<tr>
<td>Computer simulation skill available</td>
<td></td>
</tr>
<tr>
<td>Experience reading utility bills and performing regression analysis available</td>
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The above table shows that metering is essential for Options A & B, which could represent individual or limited HVAC Upgrade projects.
Basis for quantification of energy savings (ES), according to IPMVP is the following formula:

\[
ES = \text{Baseline energy consumption} - \text{Post-implementation energy consumption (Reporting Period)} \pm \text{adjustments.}
\]

Adjustments address differences in conditions between the baseline and the reporting periods.

Energy savings, according to IPMVP, can be defined either as avoided energy or normalised savings.

To collect the data required for quantification of energy saving (IPMVP), the following processes are involved:

- Visual inspection
- Sample spot measurements
- Short-term performance testing
- Data-trending and control-logic review

**Cost effective sub-metering**

Cost effective sub-metering considers an optimal number of meters, sufficient for a robust and reliable M & V system, that can determine energy savings arising from energy efficiency upgrades in a reliable way.

Cost effective sub-metering M & V system requires a comprehensive M & V plan that considers:

- Thorough knowledge of employed HVAC System (Design and operations of equipment and controls) and other energy systems.
- Thorough knowledge of electrical reticulation/switchrooms and position/loads of HVAC System components in it (represented in Electrical Single Line Diagram)
- Load measurements (to ascertain size of current transformers considering the difference between a maximum load and name plate reading)
- Thorough knowledge about trend of energy use/power demand (using utility bills and smart metering interval data) and its correlation to variable weather conditions (regression analysis using CDD and HDD – Cooling and Heating Degree Days, ands actual energy consumption data.
- Awareness of available budget
- Knowledge on cost effective meters and processing softwares
- Use of existing sub-meters (properly validated) and the likes (VSD controllers for pumps and fans with HLI- High Level Interface, temporary loggers, etc.)
- Creation of virtual meters
- Minimal ongoing fees for analysis and reporting
Case Study - an example of a cost effective multiple sub-metering arrangement

Large museum in Sydney, with a complex HVAC System (three magnetic bearing chillers, sea water CW cooling, primary and secondary CHW distribution, Condensing gas HW Heater with pumps, multiple CHW and HW AHUs with carbon filtration, Demand Ventilation, pressurisation and Economy Cycle, electric steam humidifiers, VSD controllers on all pumps and fans, electric duct heaters on FCUs, etc.) tendered for sub-metering system. Two large companies (one BMS and one specialised for sub-metering) offered around 40 sub-meters (initial capital cost around $200k with ongoing reporting fee of around $40,000 pa). They spent minimal time to get familiar with HVAC Systems and electrical reticulation. GreenKon, based on its intimate knowledge of site from previous energy auditing and HVAC Design works, has proposed much more cost effective solution for a fraction of the cost that was offered by two other competitors - $40K and $12K for ongoing reporting.

The below spreadsheet outlines this very cost effective M & V plan and sub-metering design:
Additional benefits from energy efficiency upgrades in Australia, when using a proper M & V system reduces capital cost of energy efficiency upgrades

NSW Government has introduced Energy Saving Certificates (ESCs) via Energy Saving Scheme (ESS) that can reduce capital costs of upgrades by typically 20-30%.

Verified energy savings via M & V systems, compliant with ESS’ requirements, are eligible for creation of ESCs (1x ESC equal to 1x saved CO2 tonne pa) and upfront claiming of benefits for around 6-7 years (if savings is verified using PIAMV method – Project Impact Assessment Measurement and Verification method).

Current value of 1 x ESC is around AU$ 25, so creation and sale of ESCs generated from one office building control optimisations (around 1,500 ESCs) can generate around $AU35,000 (EU 20,000).