Template/Example

Measurement and Verification Plan

For Client/Project

(Option C Small Project)

# Document Control

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| Revision No. | Date | Author | Reviewed | Approved |
| 0 | 1 April 2019 | Jack Smith | Jane Smith | John Smith |
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Contents

[Document Control 1](#_Toc6212942)

[1. Facility and Project Overview 4](#_Toc6212943)

[Stakeholders and Project Team 4](#_Toc6212944)

[Description of the Site/Facility 4](#_Toc6212945)

[Project Description 4](#_Toc6212946)

[M&V Requirements and Key Outcomes 4](#_Toc6212947)

[2. ECM Intent 4](#_Toc6212948)

[ECM Description: 4](#_Toc6212949)

[Savings achieved by: 4](#_Toc6212950)

[Affected Equipment: 4](#_Toc6212951)

[Expected Savings: 4](#_Toc6212952)

[3. IPMVP Option and Measurement Boundary 5](#_Toc6212953)

[M&V Option: 5](#_Toc6212954)

[Measurement Boundary: 5](#_Toc6212955)

[Interactive Effects: 5](#_Toc6212956)

[4. Baseline Definition 6](#_Toc6212957)

[Period: 6](#_Toc6212958)

[Energy Data: 6](#_Toc6212959)

[Independent Variables: 7](#_Toc6212960)

[Equipment Inventory 8](#_Toc6212961)

[Static Factors: 8](#_Toc6212962)

[5. Reporting Period 8](#_Toc6212963)

[Period: 8](#_Toc6212964)

[Frequency: 8](#_Toc6212965)

[Measurements: 8](#_Toc6212966)

[6. Basis for Adjustment 8](#_Toc6212967)

[Conditions 8](#_Toc6212968)

[Routine Adjustments 8](#_Toc6212969)

[Non-routine Adjustments 8](#_Toc6212970)

[7. Calculation Methodology and Analysis Procedure 9](#_Toc6212971)

[Data Analysis Procedures: 9](#_Toc6212972)

[Savings Calculation Methodology: 9](#_Toc6212973)

[Assumptions: 9](#_Toc6212974)

[8. Energy Prices 9](#_Toc6212975)

[Natural Gas: 9](#_Toc6212976)

[9. Meter Specifications 9](#_Toc6212977)

[Gas Meter: 9](#_Toc6212978)

[Meter Reading and Witnessing protocol 9](#_Toc6212979)

[Lost measurements record plan 9](#_Toc6212980)

[10. Monitoring Responsibilities 10](#_Toc6212981)

[Operational Verification: 10](#_Toc6212982)

[Collecting Energy Data: 10](#_Toc6212983)

[Collecting Independent Variable Data: 10](#_Toc6212984)

[Collecting Static Factors: 10](#_Toc6212985)

[Analysing collected data: 10](#_Toc6212986)

[Reporting Savings: 10](#_Toc6212987)

[11. Expected Accuracy 10](#_Toc6212988)

[12. M&V Budget 11](#_Toc6212989)

[13. Report Format 12](#_Toc6212990)

[14. Quality Assurance 12](#_Toc6212991)

[Data gathering quality 12](#_Toc6212992)

[Data errors 12](#_Toc6212993)

[Missing data 12](#_Toc6212994)

[Verified Savings 12](#_Toc6212995)

[Operation Performance 12](#_Toc6212996)

[Appendix 1: Heating Degree Day Data – Base Temp Best Fit Calculation 13](#_Toc6212997)

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| Facility and Project Overview |
| Stakeholders and Project Team | **Client:** ABC High School**Client Rep:** Facilities Manager**Project Manager:** Joe Blogs (Maintenance Eng)**M&V Specialist:** Jack Smith (independent) |
| Description of the Site/Facility | Location: 123 Knowall DriveType: High SchoolLarge school with a single hot water boiler supplying radiators for space heating throughout the school.. |
| Project Description | Replace aging gas fired hot water boiler with more efficient condensing boiler. |
| M&V Requirements and Key Outcomes | Crown loan has been made available to fund the boiler replacement, and it is required to demonstrate that the annual energy savings exceed annual loan repayments of $15,000.  |

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| ECM Intent |
| ECM Description: | Replace existing boiler with more efficient condensing boiler. |
| Savings achieved by: | More efficient boiler uses less gas to meet the school heating demand (winter months only). |
| Affected Equipment: | * 1500 kW Gas Fired Boiler
 |
| Expected Savings: | 277,000 kWh ($15,000) per annum |

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| IPMVP Option and Measurement Boundary |
| M&V Option: | Option C: Whole Facility While gas is used for cooking in a couple of kitchen at the School, the Hot Water Heating boiler is the single largest gas consumer at the school by far. The more efficient boiler is expected to reduce school gas consumption by at least 25%.It is also noted that the boiler is not operated due the summer months i.e. December to March (inclusive). |
| Measurement Boundary: | The Gas Utility meter that supplies gas to the boiler and some other minor gas uses.. |
| Interactive Effects: | There is no planned changes to the school heating demand and as such no interactive effects are anticipated.. |

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| Baseline Definition |
| Period: | The 12 month period of 1 April 2016 to 31 March 2017 (prior to the replacement of the boiler) |
| Energy Data: | Monthly gas consumption data was provided by the gas utility invoices as detailed in table 4.1 below. |
| Independent Variables: | 1. Heating Degrees Days – as provided by a local weather station (via [www.degreedays.net](http://www.degreedays.net)). The monthly HDDs for a range of base temperatures were obtained and the RSQR() function in excel was used to determine the base temperature that correlated the best with the Gas Consumption. The HDD base Temperature of 19.5 deg C was determined to have the best fit (refer Appendix 1 for details).
2. Number of teaching days each month is expected to have a significant impact on gas consumption.

Table 4.1: Baseline Energy and Independent Variable DataFor the summer months (Dec – Mar) when the boiler doers not operate, the baseline will be the actual consumption of the small uses (i.e. kitchens) at the school.For the months when the boiler does operate (April – Nov), the LINEST function in Excel was used to determine the regression model (and associated standard errors) for relationship between school gas consumption and the independent variables.There the monthly school gas consumption model is: Monthly Gas Use = 844 \* HDD + 4989 \* Teaching Days – 114127 kWhThe outputs from the LINEST Function were also used to determine the validity of this multivariate regression model:  |
| Equipment Inventory  | * 1 x 1500 kW gas fired Boiler
 |
| Static Factors: | * Boiler hot water return temperature set point of the return heating water temperature to the boiler.
* The radiator heating capacity (should be changes be made to radiator configuration).
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| Reporting Period |
| Period: | 12 months post installation of the new boiler. |
| Frequency: | Monthly. |
| Measurements: | * Gas consumption data as provided by the gas utility invoices.
* Monthly Heating degree days as provided by the local weather station via [www.degreedays.net](http://www.degreedays.net)
* No. of School teaching days each month as published on the school information portal.
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| Basis for Adjustment |
| Conditions | Baseline consumption will be adjusted to Reporting period conditions (i.e. avoided energy use). |
| Routine Adjustments | For the months of December to March, there are no independent variables which influence Gas Consumption and the Baseline is not adjusted.For the months when the boiler does operate (April to November) the baseline model developed for changes in ambient air temperature (heating degree days) and the number of teaching days will be used to adjust the baseline to the reporting period conditions. |
| Non-routine Adjustments | Should any boiler faults or operating parameter changes (i.e. hot water return set point) be detected during the baseline or reporting periods, then corresponding adjustments with be made. |

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| Calculation Methodology and Analysis Procedure |
| Data Analysis Procedures: | 12 months of Gas consumption data will be obtained for the reporting period along with the associated monthly HDD (base Temp = 19.5 degC) and number of teaching days.  |
| Savings Calculation Methodology: | Energy Savings are calculated using the following equation:Gas kWhsavings = Gas Adjusted Baseline kWhbase – Actual Gas kWhreporting ± adjustments |
| Assumptions: | No changes will be made to the configuration of the school radiators or the set point of the hot water return temperature to the boiler.  |

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| Energy Prices |
| Natural Gas: | Blended rate of 5.4 cents per kWh to be used for the valuation of all energy savings. |

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| Meter Specifications |
| Gas Meter: | Utility Grade Gas Meter |
| Meter Accuracy assumed to be 100%  |
| Meter Reading and Witnessing protocol | Not applicable. |
| Lost measurements record plan | All energy and independent variable data is available from on-line cloud based platforms which has minimised the risk of data loss. |

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| Monitoring Responsibilities |
| Operational Verification: | Joe Blogs (Project Manager) |
| Collecting Energy Data: | Joe Blogs (Project Manager) |
| Collecting Independent Variable Data: | Jack Smith (M&V Specialist) |
| Collecting Static Factors: | Joe Blogs (Project Manager) |
| Analysing collected data: | Jack Smith (M&V Specialist) |
| Reporting Savings: | Jack Smith (M&V Specialist) |

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| Expected Accuracy |
| Required level of Accuracy and Precision | Results to be reported with 90% probability (confidence) and ±20% precision |
| Metering equipment measurement standard error calculation | The Gas Utility Meter is assumed to be 100% accurate.The Heat Degree Day data publicly published and assumed to be 100% accurate.The schools teaching day data in also published on-line and assumed to be 100% accurate.  |
| Sampling Error Calculation | No sampling performed. |
| Modelling Uncertainty Calculation | As detailed in the Baseline development (refer Section 4) , the LINEST function in Excel was also used to determine the standard error of the baseline energy model to be **12,300 kWh.** |
| Savings Assessment Uncertainty Calculation | Savings Assessment Uncertainty Formula:$$SE\_{monthly savings}=\sqrt{(SE\_{baseline})^{2}+(SE\_{Reporting })^{2}}$$For the months of April to November:$$SE\_{monthly savings}=\sqrt{(12,300)^{2}+(0)^{2}}=12,300 kWh$$For the months of Dec to March:$$SE\_{monthly savings}=\sqrt{(0)^{2}+(0)^{2}}=0 kWh$$Note SEreporting is 0 as the actual measurements are provided by a utility meter which is assumed to be 100% accuarate.Hence the the standard error of the annual savings is: $SE\_{annual savings}=\sqrt{(12,300)^{2} x 8 months}=34,790 kWh$To calculate the confidence interval for the estimated savings ($\hat{x}$):* $\hat{x}-t∙SE\left(\hat{x}\right)\leq x\leq \hat{x}+t.SE(\hat{x})$

where:* Absolute Precision $\left(\hat{x}\right)=t∙SE(\hat{x})$
* Relative Precision $\left(\hat{x}\right)=\frac{t∙SE(\hat{x})}{(\hat{x})}$

and: t is the t-value for (n-k-1) degrees of freedom where: n = 12 (monthly samples)k = no. coefficients In baseline model = 2 |

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| M&V Budget |
| M&V Plan | $1,200 excl GST (8 hours @ $150 per hour) |
| Measurements | $1,800 excl GST (12 hours for M&V Specialist) per annum |
| Report | $3,600 excl GST (2 hours per month @ $150 per hour)  |
| Total Budget | $6,600 excl GST |

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| Report Format |
|  | The report will include at a minimum the following information:* Project background
* ECM description
* M&V Option chosen for the ECM or project
* Reporting period start and end dates
* M&V activities conducted during the reporting period, including:
* Start and end time for the measurement period
* Energy use data
* Data for independent and static variables
* Description of inspection activities conducted
* Verified saving calculations and methodology
* Provide detailed description of data analysis and methodology
* Provide an updated list of assumptions and source of data used in the calculations
* Provide details of any baseline or saving adjustments including both routine and non-routine adjustments to account for changes
* Provide details of utility costs used to calculate the reported savings
* Clear presentation of verified energy, cost savings and comparison to the proposed savings.
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| Quality Assurance |
| Data gathering quality | CMVP will be analysing and verifying |
| Data errors | Low risk with accurate utility meter data and published weather station and teaching day data. |
| Missing data | N/A |
| Verified Savings | CMVP over sight. |
| Operation Performance | Project Manager is also the school maintenance engineer and therefore accountable for operational performance. |

# Appendix 1: Heating Degree Day Data – Base Temp Best Fit Calculation

