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|  | Review of Measurement & Verification Method  for Operation in the  Victorian Energy Efficiency Target Scheme  *Abridged Version*  Report No: 160309 | |
|  | Report for | **Ms. Kathryn Lucas-Healey**  **Senior Policy Officer, Energy Efficiency**  **Department of Economic Development, Jobs, Transport and Resources**  Level 9, 121 Exhibition St  Melbourne VIC 3000 |
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**Acknowledgment**

We would like to thank the staff of the Department of Economic Development, Jobs, Transport and Resources for providing information and above all their valuable time, to enable us to conduct this survey. We gained valuable assistance from Ms. Kathryn Lucas-Healey and Ms. Emma Jacobs.

**Confidentiality**

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Yours sincerely,



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## Project Timing & Data Requirements

The following section looks at three typical projects types that may utilise the VEET M&V method. Due to the early stages of VEET regulation development, minimal commentary can be made in regards to the timing of the application process. Instead, three sample projects have been presented to demonstration the expected timelines of various projects from commencement through to certificate creation. For the purpose of a reference point, the accreditation deadlines for the NSW ESS PIAM&V method have been provided below each timeline.

The three sample timelines are for:

* Chiller replacement
* VSD installation on a ventilation fan
* Industrial air compressor upgrade

**Chiller Replacement Example**

Figure 1 demonstrates a potential timeline for a chiller replacement at an industrial manufacturing facility, where the chiller is part of a HVAC system. This shows that the total timeline from concept to implementation is quite long at approx. 18 months.



Figure 1. Chiller upgrade example timeline

It is important to note that following M&V components of this timeline:

* Baseline measurement period – 4 months
* Operating measurement period – 6 months

The full operating cycle for this HVAC system would be 12 months in order to experience a full seasonal cycle and ideally the baseline and operating measurement periods would capture at least a full operating cycle in an attempt to maximise the effective range of the models. Delaying the project to allow such measurement periods is usually not possible and therefore the measured data becomes a compromise between available timeline, critical windows (plant downtime), and effective range.

It is also important to note that there is a risk to the project’s ability to generate certificates presented by the Project Plan submission to ESC by the project implementation date. Should there be delays in the review of this project plan or worse still, the plan is not accepted by the ESC, and there is no opportunity to re-measure the baseline period or to change the measurement boundary or parameters. This is a key factor that both energy saver and the ESC must be aware of and manage carefully to ensure the eligibility of the project is not sacrificed.

**Variable Speed Drive Example**

An example of the Variable Speed Drive (VSD) installation project is provided in Figure 2. In comparison to the chiller example above, the total project timeline is very short, at a generous 3 months from identification to VEEC creation.



Figure 2. VSD project example timeline

The measurement period used for this upgrade is only 7 days for both the baseline and operating periods, yet this captures multiple occurrences of the daily operating cycle. This is possible as this ventilation fan does not have any relationship to temperature and therefore has no seasonal operating profile. If a seasonal relationship was present, the measurement cycle may look more like the periods used in the chiller example.

**Compressed Air Upgrade Example**

An industrial air compressor upgrade timeline has been presented in Figure 3 and has a project timeline of 15 months. The compressor upgrade utilised production quantities as the independent variable and is on a manufacturing site with a fairly consistent output, and as such, a measurement period of 1 month was able to provide an effective range in excess of 90%.



Figure 3. Compressed air example timeline

These example projects highlight that there is a broad range on timelines and lead times associated with different technologies. There are also other considerations associated with each project including:

* Availability of existing metering,
* Operating cycle of the system/equipment,
* Cost effectiveness/practicality of metering and sub metering,
* Interactions with other projects in the measurement boundary, and
* Ease of reversibility of the project.

The energy saver and the ESC need to be aware of the complexity of such projects and ensure that adequate resources and knowledge is applied to each project with careful management of the project timeline to ensure the eligibility of the project is not sacrificed.

# Worked Case Studies

## Case Study 1 – Co-Generation Plant

***Project Description:***

A food manufacturer based in a regional area which utilises animal products from local farmers to generate a value added raw material for other national and international food manufacturers. The site consumed approximately 160 GWh of electricity per annum and the site frequently experienced dips or brown outs of the electricity supply due to its location in a regional area. As a result of the utility tariffs and the intermittent electricity supply issues, the site investigated and subsequently implemented, a   
2 MW co-generation system.

***M&V Plan:***

The cogeneration system’s purpose is to supply a baseload electricity to the plant and steam to the manufacturing plant (to completely offset the current boilers). So the total electricity and gas supplied to the manufacturing plant was considered for the measurement boundary of the system. As such the existing utility metering for gas and electricity was utilised as the energy inputs, with detailed data provided by the energy retailers. A summary of the M&V plan and project schedule is provide in Table 1.

Table 1. Cogen System M&V Summary

|  |  |
| --- | --- |
| **Measurement and Verification Plan** | |
| M&V Method | IPMVP Option C |
| Baseline Measurement Period | 1/01/2015 – 30/6/2015 |
| Operating Measurement Period | 15/07/2015 – 31/12/2015 |
| Meter/Data Source(s) | Electricity Billing Meter – Data via MDA Web Portal  Gas Billing Meter – Data provided by Utility Supplier  Internal Production Reporting (independent variable) |
| M&V Budget | $ 6,500 |
| **Project Schedule** | |
| Project Design | February 2013 – December 2014 |
| M&V Planning | October 2014 |
| Metering & Monitoring Implementation | N/A as utility meters and production sensors were pre-existing |
| Baseline Modelling | 01/07/2015 – 14/07/2015 |
| Project Implementation and Commissioning | 01/07/2015 – 14/07/2015 |
| Operating Energy Modelling | January 2016 |
| Energy Verification | January 2016 |

***VEET Measurement & Verification Outcomes:***

The following is a summary of the models developed during the M&V along with the associated statistical parameters for validation.

Table 2. M&V Models

|  |  |  |
| --- | --- | --- |
| **M&V Model** | **Parameter** | **Value** |
| **Electricity Baseline Model** | Adjusted R2 | 0.76 |
| Standard Error | 1.44 |
| Production Coefficient | 0.322 |
| Intercept | -0.036 |
| Model Functional Form | MWh = 0.322 x Production – 0.036 |
| Independent Variable T-Stat | 24.2 |
| **Electricity Operating Model** | Adjusted R2 | 0.73 |
| Standard Error | 4.16 |
| Production Coefficient | 0.011 |
| Intercept | 3.29 |
| Model Functional Form | MWh = 0.011 x Production + 3.29 |
| Independent Variable T-Stat | 22.9 |
| **Gas Baseline Model** | Adjusted R2 | 0.61 |
| Standard Error | 20.2 |
| Production Coefficient | 0.310 |
| Intercept | 1.49 |
| Model Functional Form | GJ = 0.310 x Production + 1.49 |
| Independent Variable T-Stat | 16.7 |
| **Gas Operating Model** | Adjusted R2 | 0.96 |
| Standard Error | 36.5 |
| Production Coefficient | 0.302 |
| Intercept | 31.4 |
| Model Functional Form | GJ = 0.302 x Production + 31.4 |
| Independent Variable T-Stat | 73.6 |

Applying the models to a Normal Year of production identifies the net reduction in carbon dioxide equivalent (as shown in Figure 4). The Normal Year is based upon the independent variable of production (kg) used for development of the regression models. This Normal Year was developed from the average production levels from the previous three years in conjunction with the expected production forecasts for the next three years. These production levels were shown to be fairly consistent over this period and hence were utilised to provide an average production year. The site also experiences two scheduled shutdowns per year during October and December/January. These were taken into account as shown in Figure 4.

Figure 4. Baseline & operating models applied to the normal year

The results of applying the above models to Equations 1 and 3 of Schedule 37 are:

* Annual electricity savings of 11,120 MWh,
* Annual gas saving of – 5,897 GJ,
* Annual CO2-e abatement of 12,338 tonnes,
* Project lifetime abatement of 120,049 tonnes CO2-e

As this co-generation project exceeds the certificate limit for forward creation, the project is only eligible to create 50,000 certificates from forward creation, with the remaining certificate generated through the annual top up mechanism. As a result, further M&V would be required in the form of continuous operating period measurement in order to use the annual creation method (Equations 2 and 4 of Schedule 37). A summary of the CO2-e abatement is shown in Figure 5 where certificates from forward creation are represented in blue and annual creation in red.

Figure 5. CO2 Equivalent Forward Creation over the Project Lifetime

***Financial Analysis:***

The following is a summary of the financial impact of VEEC creation on the co-generation project:

Table 3. Project Financial Outcomes

|  |  |
| --- | --- |
| **Project Capital Cost** | $ 4.46 million |
| **Annual Energy Savings** | $ 1.5 million |
| **Simple Payback without VEEC creation** | 3.0 years |
| **ROI without VEEC creation** | 229% |
| **VEEC Forward Creation Quantity** | 50,000 |
| **Forward Creation VEEC Revenue** | $1,150,000 |
| **Subsequent Annual VEEC Creation** | 11,675 |
| **Subsequent Annual VEEC Revenue** | $ 268,525 |
| **Project Lifetime VEEC Revenue** | $ 2,761,150 |
| **Simple Payback with VEEC creation** | 1.7 years |
| **ROI with VEEC creation** | 291% |

Assumptions:

* Project capital Cost includes M&V Costs,
* Energy savings calculated based upon $0.14/kWh for electricity and $8.57/GJ for gas excluding GST,
* VEEC Market Value of $23/VEEC consistent over the life of the project,
* Analysis excludes any additional AP creation or trading fees,
* ROI calculated on a 10 year lifetime basis,
* Project lifetime VEEC revenue based on a 10 year basis,
* Subsequent annual VEEC creation is the average of the annual top up certificate quantity for the last 6 years of the project lifetime,
* Utilising an approved persistence model under the VEET M&V method.

## Case Study 2 – Cold Storage Facility

***Project Description:***

A cold storage facility within metropolitan Melbourne, that is a key link in supporting the Victorian dairy industry, investigated the potential to conduct energy efficiency projects on the refrigeration supply equipment. The site determined that approximately 70% of the site’s energy use was through refrigeration with a potential to achieve an electrical energy reduction of 10% across the site. The site implemented defrost management, VSDs on major evaporator fans and refrigerant changes on its multiple refrigeration systems.

***M&V Plan:***

A summary of the M&V plan and project schedule is provide in Table 1.

Table 4. Cold Storage Refrigeration System M&V Summary

|  |  |
| --- | --- |
| **Measurement and Verification Plan** | |
| M&V Method | IPMVP Option C |
| Baseline Measurement Period | 1/01/2014 – 30/11/2014 |
| Operating Measurement Period | 1/02/2015 – 31/05/2015 |
| Meter/Data Source(s) | Electricity Billing Meter – Data via MDA Web Portal  BOM Weather Data – BOM Subscription |
| M&V Budget | $ 4,000 |
| **Project Schedule** | |
| Project Design | October 2013 – November 2014 |
| M&V Planning | December 2014 |
| Metering & Monitoring Implementation | N/A as utility meters were pre-existing |
| Baseline Modelling | January 2015 |
| Project Implementation and Commissioning | 09/12/2014 – 22/01/2015 |
| Operating Energy Modelling | June 2016 |
| Energy Verification | June 2016 |

***VEET Measurement & Verification Outcomes:***

A regression model approach was selected for the cold storage facility project due to the size of the savings, complexity of sub metering required and the relationship between energy, temperature and operating hours. These relationships can be seen in Figure 6.

Figure 6. Electricity and Independent Variable Relationship

The following is a summary of the models developed during the M&V along with the associated statistical parameters for validation.

Table 5. M&V Models

|  |  |  |
| --- | --- | --- |
| **M&V Model** | **Parameter** | **Value** |
| **Electricity Baseline Model** | Adjusted R2 | 0.89 |
| Standard Error | 1.64 |
| Temperature Coefficient | 0.618 |
| Hours of Operation Coefficient | 0.712 |
| Intercept | 23.8 |
| Model Functional Form | MWh = 0.618 x Temperature + 0.712 x Hours +23.9 |
| Temperature Variable T-Stat | 30.2 |
| Hours of Operation Variable T-Stat | 43.1 |
| **Electricity Operating Model** | Adjusted R2 | 0.93 |
| Standard Error | 1.36 |
| Temperature Coefficient | 0.784 |
| Hours of Operation Coefficient | 0.749 |
| Intercept | 15.9 |
| Model Functional Form | MWh = 0.784 x Temperature + 0.749 x Hours + 15.9 |
| Temperature Variable T-Stat | 22.8 |
| Hours of Operation Variable T-Stat | 32.9 |

Applying the models to a Normal Year of production identifies the net reduction in carbon dioxide equivalent (as shown in Figure 7). The Normal Year is based upon the independent variables of temperature and operating hours per day used for development of the regression models. A typical meteorological year (TMY) was developed for the local region based upon historic weather data. This was combined with the scheduled operation of 12 hours on weekdays to develop the Normal Year.

The site does not experience any shutdown periods as cold storage for the product is required at all times. The electricity consumption of zero in Figure 7 represent the periods of time outside of the effective range of the M&V analysis. The total effective range is 96%.

Figure 7. Baseline & operating models applied to the normal year

The results of applying the above models to Equations 1 and 3 of Schedule 37 are:

* Annual electricity savings of 1,625 MWh,
* Annual CO2-e abatement of 1,745 tonnes,
* Project lifetime abatement of 8,257 tonnes CO2-e

As a result, this project is eligible to create 8,257 VEECs, which is worth approximately $190,000 gross (ie: before costs) at a market price of $23 per VEEC. This is utilising the default decay values (for demonstration purposes) as shown in Figure 8.

Figure 8. CO2 Equivalent Forward Creation over the Project Lifetime

***Financial Analysis:***

The following is a summary of the financial impact of VEEC creation on the cold storage refrigeration project:

Table 6. Project Financial Outcomes

|  |  |
| --- | --- |
| **Project Capital Cost** | $ 375,000 |
| **Annual Energy Savings** | $ 146,000 |
| **Simple Payback without VEEC creation** | 2.6 years |
| **ROI without VEEC creation** | 289% |
| **Forward Creation VEEC Quantity** | 8,257 |
| **Forward Creation VEEC Revenue** | $190,000 |
| **Simple Payback with VEEC creation** | 1.1 years |
| **ROI With VEEC creation** | 340% |

Assumptions:

* Project capital Cost includes M&V Costs,
* Energy savings calculated based upon $0.09/kWh for electricity excluding GST,
* VEEC Market Value of $23/VEEC consistent over the life of the project,
* Analysis excludes any additional AP creation or trading fees,
* ROI calculated on a 10 year lifetime basis,
* Project lifetime VEEC revenue based on a 10 year basis,
* Utilising the default decay values under the VEET M&V method for the purpose of demonstration.

## Case Study 3 – Fixed Speed to Variable Speed Motor

***Project Description:***

A maintenance workshop within a local council facility requires continuous ventilation to ensure carbon monoxide levels are maintained within safe operating thresholds. The site was aiming to maintain CO levels below 25 ppm. The ventilation fan is rated at 22 kW (nameplate) and operates on a belt and pulley configuration. Historically, the ventilation fan for this area operated at a fixed speed, regardless of the CO levels within the workshop. An energy efficiency opportunity was identified to change the fan to a Variable Seed Drive control system linked to a network of CO sensors within the workshop. This allowed the fresh air flow rate supplied to the workshop to be reduced when CO levels are low and increase ventilation as CO levels increase.

***M&V Plan:***

A summary of the M&V plan and project schedule is provide in Table 7.

Table 7. Ventilation System M&V Summary

|  |  |
| --- | --- |
| **Measurement and Verification Plan** | |
| M&V Method | IPMVP Option B |
| Baseline Measurement Period | 1/03/2015 – 07/03/2015 |
| Operating Measurement Period | 21/03/2015 – 27/03/2015 |
| Meter/Data Source(s) | Electricity – Power meter installed on ventilation fan  CO Levels – 8 Sensors located throughout workshop. Average of 8 sensors provide the CO levels (PPM).  Ventilation Flow Rate – Anemometer installed in ventilation ductwork to measure air flow rate from the fan. |
| M&V Budget | $ 3,000 |
| **Project Schedule** | |
| Project Design | January 2015 |
| M&V Planning | January 2015 |
| Metering & Monitoring Implementation | February 2015 |
| Baseline Modelling | 1/03/2015 – 07/03/2015 |
| Project Implementation and Commissioning | 08/03/2015 – 20/03/2015 |
| Operating Energy Modelling | April 2015 |
| Energy Verification | April 2015 |

***VEET Measurement & Verification Outcomes:***

An average energy model approach was selected for the ventilation fan project due to the fan operation not being related to CO levels before the project implementation. This can be seen in Figure 9 and Figure 10.

Figure 9. Time Series Plot of Electricity, CO Levels and Flow Rate

Figure 10. Scatter Plot of CO Levels and Electricity Consumption

After the implementation of the project, the relationship between fan energy, air flow rate and CO levels changed due to the introduction of the VSD and control loop. During the operating period, the fan energy consumption is shown to have a strong correlation with air flow as seen in Figure 11. As such, a regression model approach was utilised for the operating period.

Figure 11. Operating Period Scatter Graph of Fan Energy vs. Air Flow Rate

The following is a summary of the models developed during the M&V along with the associated statistical parameters for validation.

Table 8. Average M&V Models for Ventilation System

|  |  |  |
| --- | --- | --- |
| **M&V Model** | **Parameter** | **Value** |
| **Electricity Average Baseline Model** | Average Energy Model | 0.02076 MWh/hr |
| Standard Error | 0.00004 |
| Coefficient of Variance | 0.028 (2.8%) |
| Absolute Precision | ± 0.00006 MWh |
| Relative Precision | 0.27% |
| **Electricity Regression Operating Model** | Adjusted R2 | 0.92 |
| Standard Error | 0.00084 |
| Flow Rate Coefficient | 0.0024 |
| Intercept | -0.0027 |
| Model Functional Form | MWh = 0.0024 x Flow Rate – 0.0027 |
| Flow Rate Variable T-Stat | 44.1 |

Applying the baseline and operating models to a Normal Year of carbon monoxide levels (independent variable) is shown in Figure 12. The Normal Year for this period was developed by replication of the weekly average carbon monoxide levels observed throughout the measurement period.

Figure 12. Baseline & operating models applied to the normal year

The results of applying the above average energy models to Equations 1 and 3 of Schedule 37 with an approved persistence model are:

* Annual electricity savings of 148 MWh,
* Annual CO2-e abatement of 168 tonnes,
* Project lifetime abatement of 1,659 tonnes CO2-e

As a result, this project is eligible to create 1,666 VEECs, which is worth approximately $38,300 gross (ie: before costs) at a market price of $23 per VEEC.

***Financial Analysis:***

The following is a summary of the financial impact of VEEC creation on the VSD ventilation project:

Table 9. Project Financial Outcomes

|  |  |
| --- | --- |
| **Project Capital Cost** | $21,000 |
| **Annual Energy Savings** | $6,500 |
| **Simple Payback without VEEC creation** | 3.2 years |
| **ROI without VEEC creation** | 210% |
| **Forward Creation VEEC Quantity** | 1,659 |
| **Forward Creation VEEC Revenue** | $38,000 |
| **Simple Payback with VEEC creation** | 0.5 years |
| **ROI With VEEC creation** | 391% |

Assumptions:

* Project capital Cost includes M&V Costs,
* Energy savings calculated based upon $0.044/kWh for electricity excluding GST,
* VEEC Market Value of $23/VEEC consistent over the life of the project,
* Analysis excludes any additional AP creation or trading fees,
* ROI calculated on a 10 year lifetime basis,
* Project lifetime VEEC revenue based on a 10 year basis,
* Utilising the persistence model under the VEET M&V method for the purpose of demonstration.

## Key Case Study Findings

Utilising the VEET M&V method for three case studies provided an opportunity to assess the functionality of the method. The following is a summary of the findings from the case study projects.

**Project Eligibility**

The cogeneration project case study was successfully able to demonstrate that the VEET M&V method is able to be applied to an energy efficiency project involving multiple energy sources. The forward creation mechanism was utilised for this case study however the maximum forward creation limit of 50,000 certificates was quickly reached.

This project is eligible to forward create up to 50,000 certificates with the remainder of the certificates available through the annual creation mechanism. As a result, further M&V would be required in the form of continuous operating period measurement in order to use the annual creation method. This limit of certificate forward creation is sensible as it limits risk to the scheme’s integrity, however it does extend the cash flow period from certificates (over 10 years) for end users and exposes them to the risk of other system changes outside of the project scope. This may provide a minor level of discouragement for the participation of some end users. Overall, a sensible balance has been achieved.

**Average Energy Model Coefficient of Variation**

Case Study 3 tested the capacity of the average energy model approach. Schedule 37, Division 2 – Variables, Baseline Energy Model and Operating Energy Model clause 1(b)(ii) required baseline and/or operating average energy to have a coefficient of variance less than 15%. As a result, this project is required to use an average energy model for the baseline and a regression operating energy model. This involves utilising two separate functional forms of energy models to forecast savings. As such, “normalisation” to a Normal Year cannot be conducted between an average energy model and a regression energy model.

An arbitrary threshold of 15% has been set for the coefficient of variation in order for an average energy model to be utilised. This is to avoid APs from unnecessarily utilising an average energy model approach in preference to the more rigorous regression model approach. This is sensible as it will encourage a consistent approach to M&V across a range of APs and also ensure average energy models are only utilise under appropriate circumstances. In order to clarify the use of average energy models, it is highly recommended that the words “independent variables (if any) and site constants” be removed from schedule s3 in relation to average energy models. The inclusion of these words implies independent variables and site constants should be included in the average energy model. Including these components results in a misinterpretation of baseline energy consumption and an incorrect M&V analysis.

Through the three case studies, it has been shown that the proposed VEET M&V method has adequate flexibility to handle a variety of energy efficiency projects. This is possible largely due to the inclusion of:

* Both a forward creation and annual creation methods, and
* Flexibility in the design of the average energy model approach.