Measurement and Verification of Energy Savings from Energy Efficiency Projects at selected NSW Government sites

Office of Environment & Heritage
Peer reviewed by Energetics

Energetics developed the measurement and verification model used by the Office and the Environment and Heritage. It is Energetics' opinion that the results contained in this report are consistent with the principles contained in the International Performance Measurement Verification Protocol (IPMVP).

While Energetics can verify the model and OEH's application of the model to the projects covered by this report, it cannot verify the accuracy of the source data used to produce the results contained within this report.

Contents

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1. Introduction

1.1. Purpose of this report

NSW Office of Environment and Heritage (OEH) / Energy Efficient Government (EEG) provided funding to a number of government organisations to implement energy and water conservation measures as part of the Government Building Retrofit Program. The purpose of this report is to provide feedback on the savings achieved at the selected sites. Savings have been determined via the application of recognised measurement and verification (M&V) methodologies.

Measurement and Verification is the process of using 'measurement' to reliably 'verify' actual savings for energy, cost and greenhouse gases at a site by an Energy Conservation Measure (ECM). Measurements are used to verify savings, rather than applying deemed savings or theoretical engineering calculations, which are usually based on previous studies, manufacturer provided information or other indirect data. Savings are determined by comparing post-retrofit performance against a 'business as usual' forecast.

1.2. Scope

Seven sites had M&V analysis performed, these included: four police stations, one sport and recreation centre, one hospital and the Australian Museum.

1.3. M&V 'the approach'

There are four available M&V Options (A, B, C, D), or methodologies, for performing M&V under the International Performance Measurement Verification Protocol (IPMVP). For a complete understanding of M&V please refer to the following link
http://www.environment.nsw.gov.au/resources/climatechange/120990bestpractice.pdf

This report details M&V assessments undertaken using Option C. The Option C methodology is summarised as follows:

- A valid energy model (refer to Appendix) is developed to describe how energy use varies in relation to a number of key parameters (e.g. ambient temperature, hospital beds, etc.). The energy model is produced by using techniques such as regression spanning the baseline period (generally 12 months or greater), which is then extrapolated for the post-retrofit period. The primary challenges are to identify and incorporate all routine and non-routine Adjustments. This option typically makes use of existing utility meters and/or energy invoices in determining the savings from the combined effect of all ECMs.
- It is recommended that this option only be used when the sum of the savings across all ECMs are expected to be greater than 10% of the site energy consumption and where the savings from each type of retrofit is not required.

1.4. Interpreting the Case Study Energy Models

The 'blue, grey and red portions' of the graphs are monthly electricity consumption figures. The 'black line' above the 'blue portion' of the graph is the modelled consumption based upon routine and non-routine adjustments, followed by regression techniques. In a valid model the 'black line' is extrapolated into the future and it is known as the adjusted baseline. Savings per month are determined to be the differences between the 'red bar' and the 'black line'.

2. Project Summary

Site	Modelled Usage (kWh or MJ)	Actual Usage (kWh or MJ)	Savings (kWh or MJ)	Savings (%)	Baseline Model Uncertainty @ 95%	Greenhouse Gas Emission Reduction (tonne) A*	Post Retrofit Period (months)	Implementation Cost ($)	Modelled Cost Savings ($) B*	Modelled Payback (Years) C*
Newcastle Police Station	1,128,745	833,804	294,941	26.1	11.1%	310	8	$358,955	$53,089	4.5
Charlestown Police Station	124,282	94,793	29,489	23.7	8.3%	31	10	$41,661	$5,308	6.5
Nowra Police Station	328,414	290,382	38,032	11.6	11.1%	40	9	$71,532	$6,846	7.8
Wollongong Police Station	664,485	588,935	75,550	11.4	5.9%	79	8	$118,059	$13,599	5.8
Westmead Hospital	20,402,759	17,816,563	2,586,196	12.7	19.1%	2,716	18	$1,560,000	$465,515	5.0
Myuna Bay Sports Centre	935,568	850,325	85,243	9.1	16.0%	90	18	$94,420	$15,344	9.2
Australian Museum	5,687,708	4,338,735	1,348,973	23.7	5.6%	1,416	13	Total $1,790,531 (OEH portion $450,000)	$252,258	NA

A* @1.05t/MWh electricity; Australian National Greenhouse Accounts Factors July 2013;

B* @ 18c/kWh electricity;

C* Savings have been pro-rated / extrapolated in order to approximate an annual saving to inform a simple payback period;

3. Case Studies

3.1. Police Stations

Eighteen (18) (listed below) Police Stations in NSW participated in the NSW Government Building Retrofit Program (GBRP) by having energy efficient and/or water efficient retrofits installed:

- Branxton
- Cessnock
- Charlestown
- Clarence Town
- Karuah
- Maitland
- Morpeth
- Newcastle
- Berry
- Corrimal
- Culburra
- Dapto
- Huskisson
- Kangaroo Valley
- Kiama
- Nowra
- Sussex Inlet, and
- Wollongong.

Newcastle, Charlestown, Nowra and Wollongong Police Stations are representative of the works undertaken and these sites have had M&V undertaken in this report.

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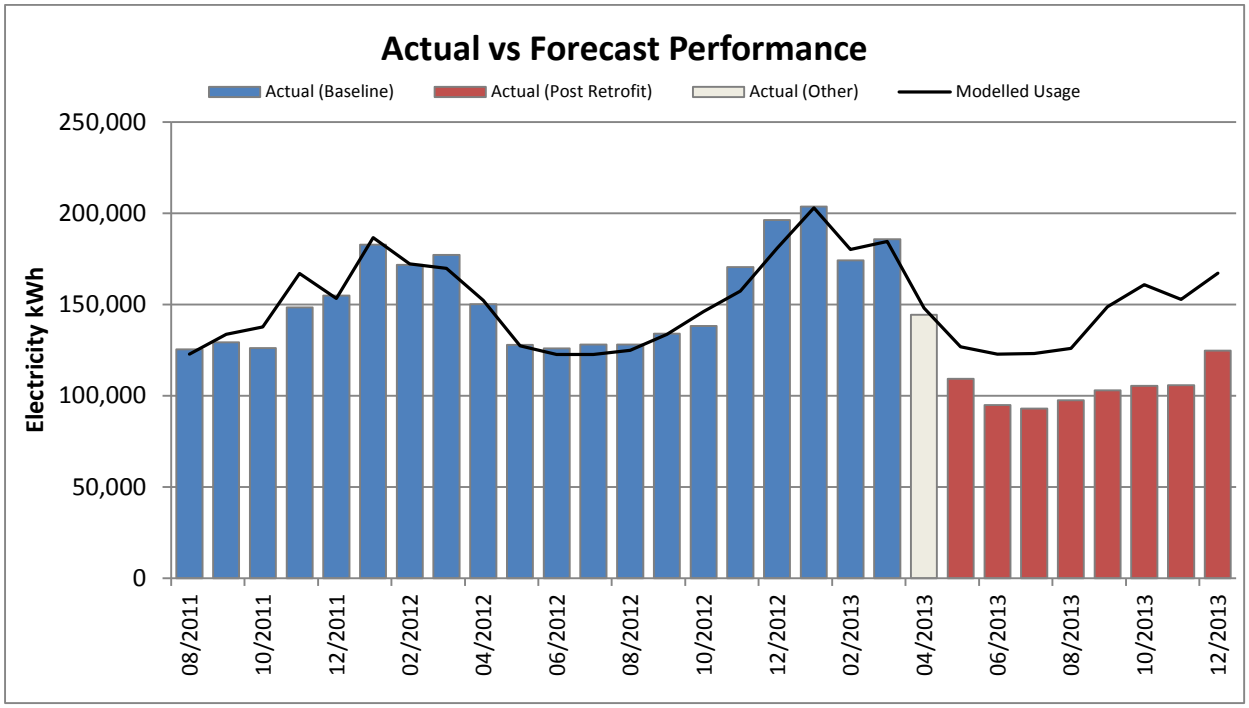
3.1.1. Newcastle Police Station



An energy model was created for Newcastle Police Station (displayed above). Electricity savings are in the order of 26% for the period May 2013 – December 2013. Savings are stated as per the following;

294,941kWh +/- 11.1% over 8 months

In Summary

NSW Police implemented multiple ECMs with the majority of the ECMs being associated with lighting upgrades. Works at Newcastle Police Station commenced in April 2013 and practical completion was deemed in May 2013. Funding for the works was provided by OEH. Works were extensive and included a major upgrade to the lighting, ventilation and plumbing; no electricity savings are associated with the plumbing works.

The Site

Newcastle Police Station is located within the Northern Region Newcastle City Local Area Command and they provide a comprehensive, professional community-based policing service.

Energy & Water Conservation Measures

Lighting

A total of 793 twin 20watt and 40watt linear fluorescent rapid start light fittings were replaced with single 18watt and 36watt linear fluorescent light fittings with electronic ballasts and high performance reflectors.

A total of 27 ‘mercury vapour’ and ‘metal halide’ high intensity discharge (HID) light fittings were replaced with either 15watt or 85watt LED light fittings.

A total of 235 single and twin 40watt and 65watt linear fluorescent rapid start light fittings were re-lamped with single and twin 18watt and 25watt LED lamps across the car park.

Ventilation

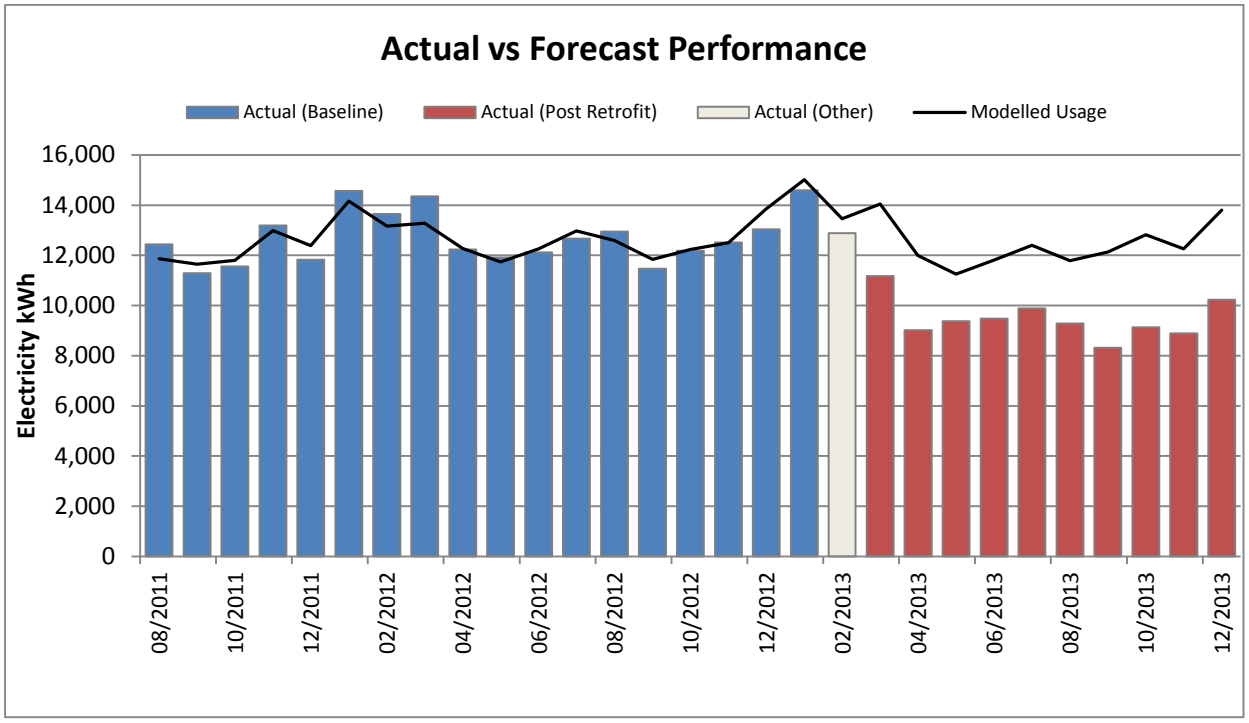
Carbon monoxide sensors and variable speed drives (VSD’s) were installed in the car park exhaust and supply systems. The sensors provide feedback to the monitoring system which adjusts the VSD’s to ensure that air quality levels are maintained at minimal energy consumption.

Plumbing

A total of 86 water saving devices were fitted across kitchens, bathrooms and toilets resulting in an estimated saving of 2,209kL/annum.

- 41 water restriction devices were fitted in toilet basins and kitchen sinks.
- 10 shower heads were retrofitted with 3 star WELS rated units.
- 25 toilets and 10 urinals were retrofitted.

3.1.2. Charlestown Police Station



An energy model was created for Charlestown Police Station (displayed above). Electricity savings are in the order of 23% for the period March 2013 – December 2013. Savings are stated as per the following;

29,489kWh +/- 8.3% over 10 months

In Summary

NSW Police implemented multiple ECMs with the majority of the ECMs being associated with lighting upgrades. Works at Charlestown Police Station commenced in February 2013 and practical completion was deemed in March 2013. Funding for the works was provided by OEH. Works were extensive and included a major upgrade to the lighting and plumbing; no electricity savings are associated with the plumbing works.

The Site

Charlestown Police Station is located within the Northern Region Central Hunter Local Area Command and they provide a comprehensive, professional community-based policing service.

Energy & Water Conservation Measures

Lighting

A total of 126 twin 20watt and 40watt linear fluorescent rapid start light fittings were replaced with single 18watt and 36watt linear fluorescent light fittings with electronic ballasts and high performance reflectors.

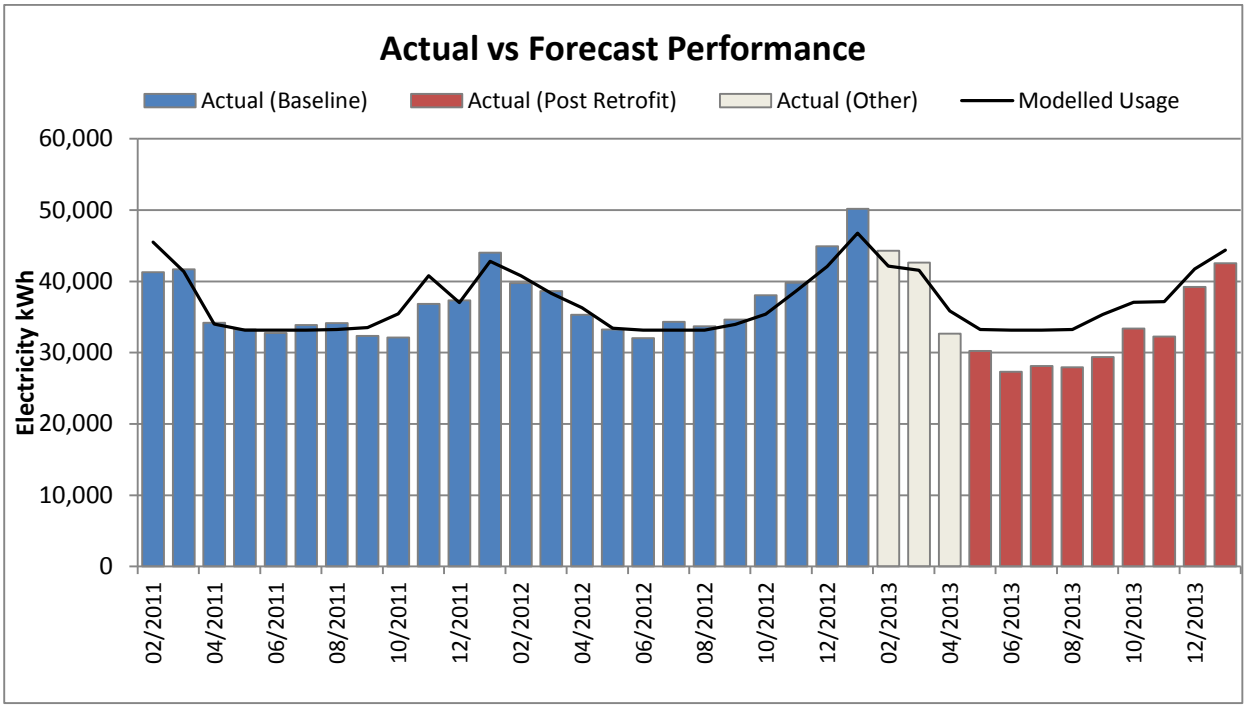
A total of 22 occupancy sensors were installed to control lighting and/or exhaust fans according to occupancy

Plumbing

A total of 15 water saving devices were fitted across kitchens, bathrooms and toilets resulting in an estimated saving of 170kL/annum.

- 6 water restriction devices were fitted in toilet basins and kitchen sinks.
- 2 shower heads were retrofitted with 3 star WELS rated units.
- 7 toilets were retrofitted.

3.1.3. Nowra Police Station



An energy model was created for Nowra Police Station (displayed above). Electricity savings are in the order of 11% for the period May 2013 – January 2014. Savings are stated as per the following;

38,032 kWh +/- 11.1% over 9 months

In Summary

NSW Police implemented multiple ECMs with the majority of the ECMs being associated with lighting upgrades. Works at Nowra Police Station commenced in February 2013 and practical completion was deemed in May 2013. Funding for the works was provided by OEH. Works were extensive and included a major upgrade to the lighting and plumbing; no electricity savings are associated with the plumbing works.

The Site

Nowra Police Station is located within the Southern Region Shoalhaven Local Area Command and they provide a comprehensive, professional community-based policing service.

Energy & Water Conservation Measures

Lighting

A total of 252 twin 20watt and 40watt linear fluorescent rapid start light fittings were replaced with single 18watt and 36watt linear fluorescent light fittings with electronic ballasts and high performance reflectors.

A total of 20 ‘mercury vapour’ high intensity discharge (HID) light fittings were replaced with 35watt LED light fittings.

A total of 20 ‘exit sign’ fittings were replaced with 2.5watt LED fittings.

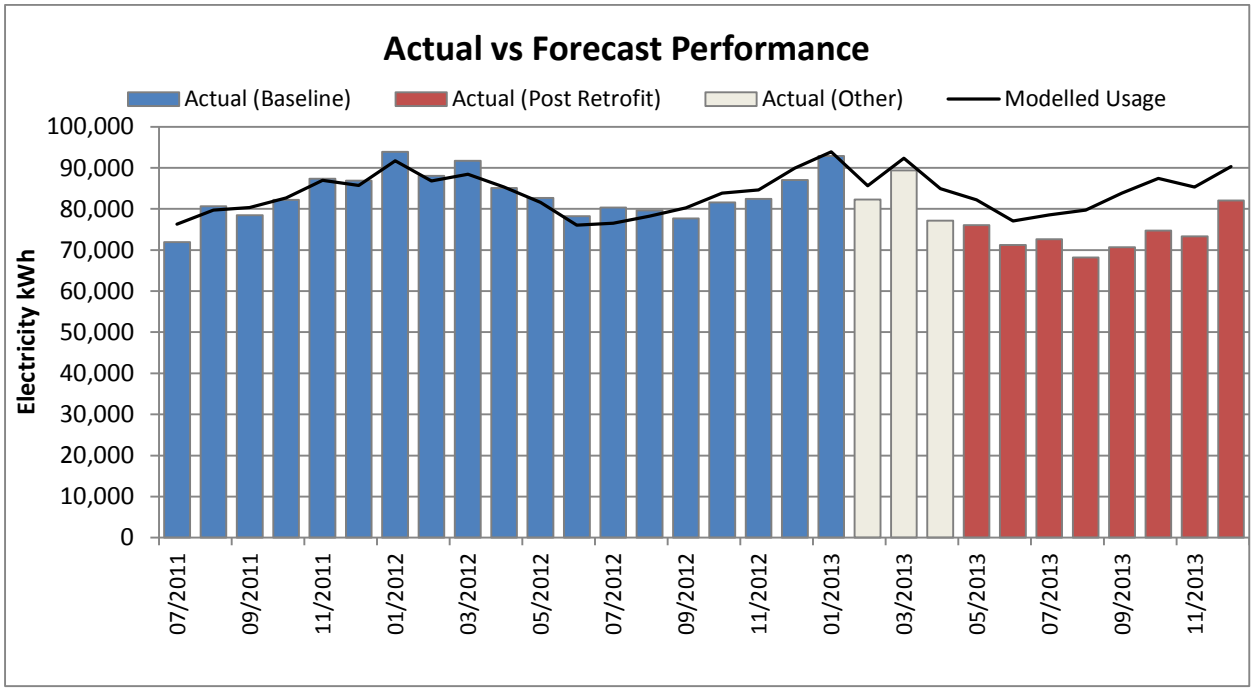
A total of 14 occupancy sensors were installed to control lighting according to space occupancy.

Plumbing

A total of 26 water saving devices were fitted across kitchens, bathrooms and toilets resulting in an estimated saving of 703 kL/annum.

- 14 water restriction devices were fitted in toilet basins and kitchen sinks.
- 4 shower heads were retrofitted with 3 star WELS rated units.
- 8 toilets were retrofitted.

3.1.4. Wollongong Police Station



An energy model was created for Wollongong Police Station (displayed above). Electricity savings are in the order of 11% for the period May 2013 – December 2013. Savings are stated as per the following;

75,550 kWh +/- 5.9% over 8 months

In Summary

NSW Police implemented multiple ECMs with the majority of the ECMs being associated with lighting upgrades. Works at Wollongong Police Station commenced in February 2013 and practical completion was deemed in May 2013. Funding for the works was provided by OEH. Works were extensive and included a major upgrade to the lighting and plumbing.

The Site

Wollongong Police Station is located within the Southern Region Wollongong Local Area Command and they provide a comprehensive, professional community-based policing service.

Energy & Water Conservation Measures

Lighting

A total of 390 twin 20watt and 40watt linear fluorescent rapid start light fittings were replaced with single 18watt and 36watt linear fluorescent light fittings with electronic ballasts and high performance reflectors.

A total of 2 ‘metal halide’ high intensity discharge (HID) light fittings were replaced with 35watt LED light fittings.

A total of 32 ‘exit sign’ fittings were replaced with 2.5watt LED fittings.

A total of 20 occupancy sensors were installed to control light according to space occupancy.

Plumbing

A total of 42 water saving devices were fitted across kitchens, bathrooms and toilets resulting in an estimated saving of 731kL/annum.

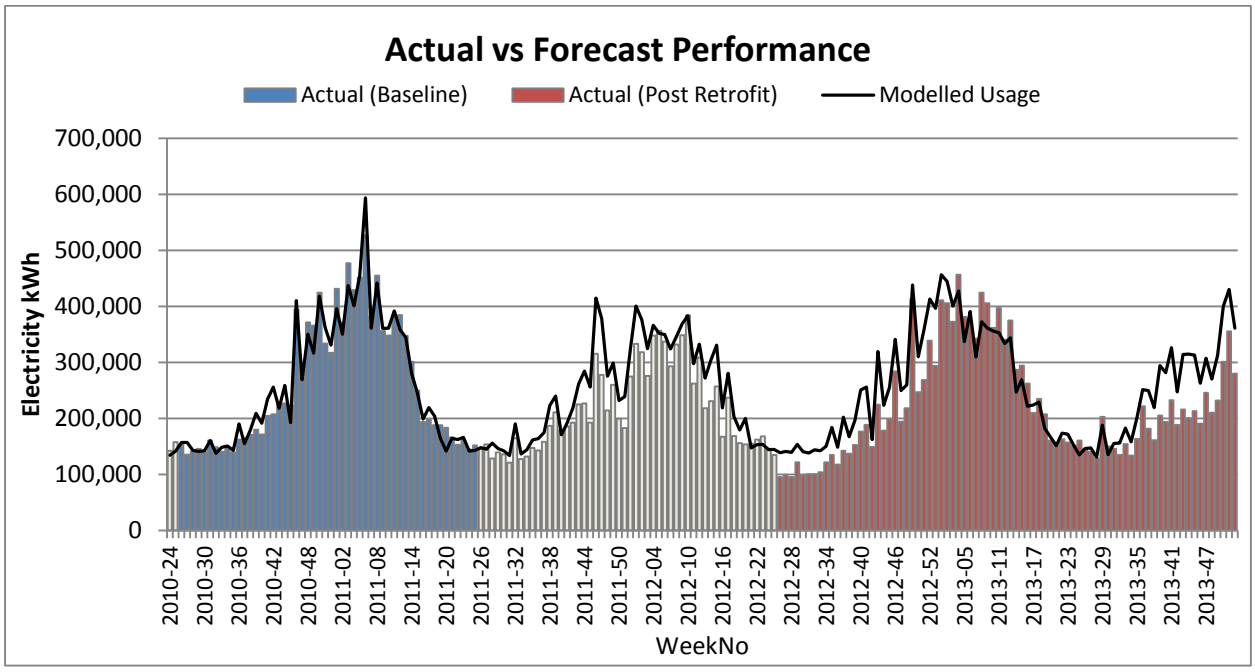
- 17 water restriction devices were fitted in toilet basins and kitchen sinks.
- 7 shower heads were retrofitted with 3 star WELS rated units.
- 14 toilets and 4 urinals were retrofitted.

Hot Water

A heavy duty electric hot water storage system was retrofitted with a bank of electric heat pump hot water units.

3.2. Hospitals

3.2.1. Westmead Hospital



An energy model was created for NSW Health at Westmead Hospital 'Mechanical Services' central plant (displayed above). Electricity savings are in the order of 12.7% for the period July 2012 – December 2013. Savings are stated as per the following;

2,586,196kWh +/- 19.1% over 18 months

In Summary

Western Sydney Local Health District / Westmead Hospital implemented multiple ECMs. Works commenced in June 2011 and practical completion was deemed in July 2012. Funding for the works was provided by both NSW Health and OEH via Crown finance. The works were extensive and consisted of a major upgrade to the central cooling system which included the replacement and optimisation of chillers, pumps, cooling towers and controls.

The Site

Westmead Hospital is a specialised tertiary referral hospital for the western Sydney metropolitan area, serving one of the largest growing population areas in NSW. With 176,000 square metres of air conditioned space. It is located in western Sydney adjacent to the city of Parramatta. For more information visit http://www.wslhd.health.nsw.gov.au/Westmead-Hospital/About-us

Energy Conservation Measures

Four chillers provide cooling to all the main buildings of the hospital. Two of the chillers with a capacity of 2,800kW$_t$ and 3,700kW$_t$ were replaced with 2 new Trane variable flow centrifugal chillers with a capacity of 4,000kW$_t$ each.

Two additional cooling towers were installed to provide a 15% increase in heat rejection capacity for the new chillers. The cooling towers were also re-configured to enable a more effective bypass with the additional cooling towers enhancing the ability to control condenser water temperatures and thus further optimise chiller performance.

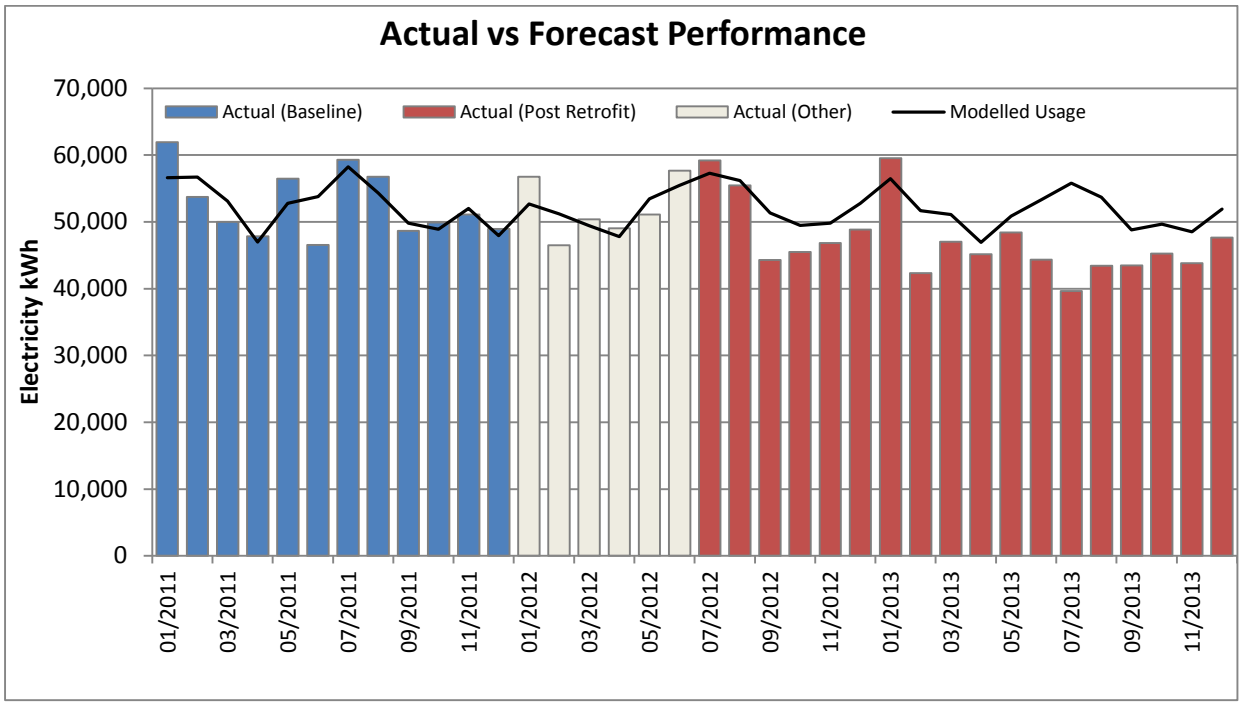
Six condenser water pumps of varying capacity (45kW to 110kW) served the cooling towers. Four of the pumps were replaced with new pumps correctly sized for the application so that they would operate closer to their peak efficiency. All six pumps were installed with variable speed drives (VSD's) to further optimise flow to the cooling towers as well as minimising electricity consumption particularly during Autumn, Winter and Spring.

Six new chilled water pumps of 75kW capacity replaced the old chilled water pumps. The pumps were replaced with new pumps correctly sized for the application so that they would operate closer to their peak efficiency. All six pumps were installed with variable speed drives (VSD's) to further optimise flow to the buildings as well as minimising electricity consumption particularly during Autumn, Winter and Spring.

Significant upgrades were undertaken with the Building Management System (BMS). The existing Honeywell control system for the central plant was replaced with a new Trane/Dalkia control system. This Trane/Dalkia control system is best matched to the new Trane variable flow centrifugal chillers. The scope of the Trane/Dalkia control system was extended to the secondary chilled water pumps allowing improved control strategies of the chillers/primary and secondary chilled water loops as well as the condenser water loop, thus encompassing the entire central plant. Post commissioning (fine tuning) of the total cooling system is ongoing with complexities around maintaining chilled water pressure to peripheral areas of the hospital as well as realising further energy savings.

3.3. Office of Communities

3.3.1. Myuna Bay Sport and Recreation Centre



An energy model was created for the Myuna Bay site (displayed above). Electricity savings are in the order of 9% for the period July 2012 – December 2013. Note that the savings achieved do not meet the general requirement of 10% of site energy consumption for an Option C analysis. The results have been included to provide an indication of savings achieved from the retrofit. Savings are stated as per the following;

85,243 kWh +/- 16% over 18 months

In Summary

Significant works were undertaken across 2 stages at the site in 2012/13. From February 2012 – June 2012 (Stage 1) and from May 2013 – July 2013 (Stage 2) the Energy Efficient Government (EEG) team identified and implemented multiple ECMs. Funding for Stage 1 and Stage 2 was provided by OEH. Of note:

- energy consumption during the Winter of 2013 is reduced further when compared to the Winter of 2011 and 2012; this is likely due to the replacement of electric underfloor resistive heating with overhead electric infra-red (IR) radiant heating panels in the Dining Hall.

The Site

The Sport and Recreation site is located on the foreshore of Lake Macquarie. Myuna Bay is about an hour and a half hour's drive north of Sydney and about 40 minutes south of Newcastle. It has occupancy for 240 guests.

For more information visit http://www.dsr.nsw.gov.au/myunabay/index.asp

Stage 1 Energy & Water Conservation Measures

Lighting

A total of 35 ‘exit sign’ fittings did not meet relevant codes and were replaced with 2.5watt LED equivalent fittings.

Hot Water

A total of 11 existing Boiling Water Unit’s (BWU’s) were provided with improved controls to minimise ‘out of hours’ operation.

A total of 72 shower heads were retrofitted across the site with 3 star WELS rated shower heads to reduce both potable water and electricity consumption.

A total 2 Pre-Rinse Spray Valves (PRSV’s) in the commercial kitchen were replaced with 6 star WELS rated units to reduce both water and electricity consumption.

A total of 4 ‘24’ hour timers were installed to control the reticulation pumps associated with the accommodation buildings hot water systems. This timer reduced ‘out of hours’ operation of the reticulation pumps saving electricity at the pumps and from at the hot water systems.

Stage 2 Energy & Water Conservation Measures

Space Heating

The Dining Hall had electric underfloor resistive heating that provided space heating to the occupants within the dining hall. The system was very slow to react to the needs of the occupants and thus the system was left activated for extensive periods (12 – 24 hours/day) between March and October of each year (dependent upon local weather conditions). This space heating was decommissioned and replaced with 8 overhead electric (IR) radiant heating panels. The panels are controlled via localised switching and deactivate after an hour of operation.

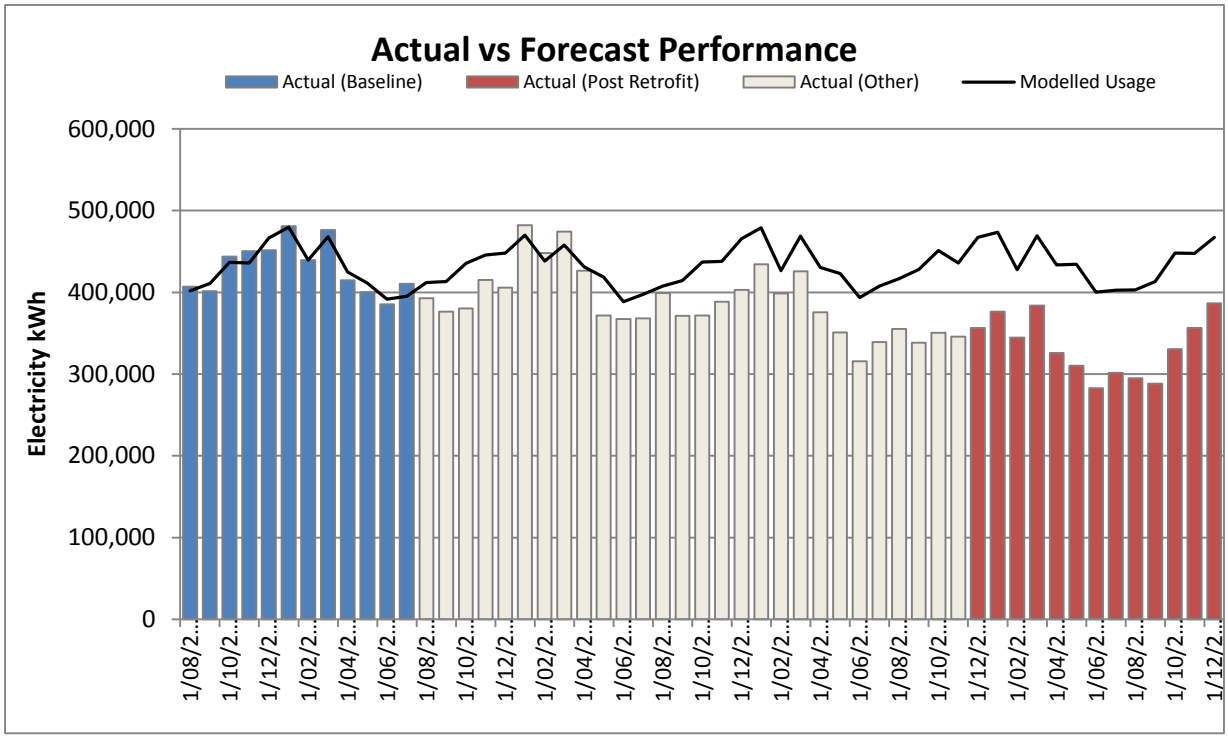
Hot Water

A total of 2 solar hot water systems were installed to pre-heat the existing heavy duty electric hot water systems for two of the accommodation buildings; ‘The Vines’ and ‘Fernholme’. This reduced the quantity of water requiring heating in the heavy duty electric hot water systems. Both systems were configured with 4 solar hot water panels and 900 litres of hot water storage.

A bank of 6 electric heat pumps replaced the existing heavy duty electric hot water system for the accommodation building; known as ‘Lakeview’.

An electric heat pump was installed to pre-heat the existing heavy duty electric hot water system for the ‘Kitchen’.

3.4. Australian Museum



An energy model was created for the Australian Museum (displayed above). Electricity savings are in the order of 23.7% for the period December 2013 – December 2014. Savings are stated as per the following;

1,348,973kWh +/- 6.43% over 13 months

In Summary

The Australian Museum implemented multiple ECMs across 3 stages at the site. From August 2011 – October 2012 (Stage 1) the Australian Museum trialled reducing space conditioning in the 'Collection Stores' during 'out of hours' periods. This trial resulted in electricity savings in the order of 5.7% or 365,080 kWh +/- 5.6% @ 95% confidence. From November 2012 – November 2013 (Stage 2) works included upgrades to the cooling towers, installation of the de-humidification units, the installation of sensors and the application of variable speed drives (VSD's). From August 2013 – November 2013 (Stage 3) works included the replacement of the lead chiller, further VSD installations and a major upgrade to the Building Management System (BMS). Funding for Stage 2 and Stage 3 was provided by both the Australian Museum and by OEH. Electricity savings are in the order of 10% for the period August 2011 – November 2013 (Stage 1 – Stage 3). Savings are stated as per the following; 1,208,104kWh +/- 10.53%. Of note;

- space conditioning is now also provided to the Vernon Wing, a floor area ~1,000m^2 ie, an additional 1/6 of the building now has space conditioning. Energy savings have not been modelled to include this additional floor area and thus actual energy savings are greater than the savings stated in this report.
- Stage 2 and Stage 3 works have enabled greater control of relative humidity and this has enabled the Australian Museum greater opportunity to host overseas exhibitions.

The Site

The Australian Museum is one of only a few institutions in the world that combines extensive collections, scientific research and public programs. Established in 1827, it was the first Museum in Australia. The evolution of the current College Street site has taken place from the 1840s to the present

day, with the Museum's first exhibition opening in 1854 (officially opened in 1855). Additional buildings followed with the most recent being the Collections & Research Building which was completed in 2008. The Australian Museum is respected for its public exhibitions, educational programs, innovative scientific research and a repository of significant collections pertaining to the natural history and cultures of Australia and the Pacific.

For more information visit http://australianmuseum.net.au/

Stage 1 Energy Conservation Measures

Museums are required to meet critical air quality standards. The Museum trialled switching off the heating ventilation and air conditioning (HVAC) system for 4 – 5 hours/night during the shoulder seasons. The BMS would monitor the relative humidity and temperature and reactivate the HVAC system when limits were exceeded. Savings during this period are clearly displayed in the model for the months August 2011 – December 2011 and May 2012 – October 2012.

Stage 2 Energy Conservation Measures

Museums require critical control over humidity to preserve their collections and to gain the opportunity to exhibit overseas collections. Traditionally the control of humidity has been achieved by 'overcooling and re-heating' the conditioned air, i.e. operating the chillers at a lower chilled water temperature to remove the humidity and then re-heating this air to room temperature. This process drives the chillers harder consuming more electricity. The Museum realised that if the outside air could be pre-treated (de-humidified) then:

- greater control could be gained over the level of humidity, and thus providing greater confidence for overseas exhibitions.
- there would be less need for 'overcooling and re-heating' and thus saving energy.

Three de-humidification units were installed to pre-treat the outside air.

The monitoring of background carbon dioxide (CO_2) levels within a conditioned space is a proven method to reduce the flow of air and the quantity of outside air into the conditioned space; energy consumption is reduced without affecting indoor air quality levels. 14 CO_2 monitors were installed within selected 'return air ducts' to provide feedback to the BMS to better manage the outside air requirements within the confined space. 10 VSDs were installed to selected air handling units (AHUs) to reduce air flow rates within the associated confined spaces whilst still maintaining air quality levels.

Installation of an additional 2 cooling towers and the reconfiguration of the cooling towers was undertaken to improve the efficiency of the cooling towers 'as a whole'.

Stage 3 Energy Conservation Measures

The central plant consisting of 4 chillers were reconfigured with a new common header and associated pipework, this improved redundancy and also allowed greater optimisation (sequencing) of the chillers.

The central plant's new associated pipework allowed the installation of 20 VSDs on chilled water and condenser water pumps.

The lead chiller was replaced with a 1,830 kW_t PowerPax oil free magnetic bearing chiller.

Significant upgrades were undertaken with the BMS. Originally there were two control systems on site; a Carrier system controlling the demand for heating and cooling services via the AHUs, while a Dalkia system would control the supply of heating and cooling services from the central plant via the chillers, boilers and cooling towers. To optimise the HVAC system 'as a whole' the control of the central plant was integrated into an upgraded Carrier system. The upgraded system is now able to include feedback from the newly installed CO_2 sensors and apply this feedback to the control of the VSDs within the AHU's to reduce air flow in the building and adjust the requirements of outside air; also the optimisation of the central plant (boilers, chillers, chilled water pumps, condenser water pumps, cooling towers) are now able to be undertaken resulting in significant energy savings.

4. Appendix

4.1. A Valid Energy Model

A valid energy model generally includes the following:

- a baseline period of 12 months or more
- A range of statistical tests relating to the regression analysis are applied to show that a minimum criteria are met, and that a known degree of certainty is achieved by the energy model itself and the calculated savings. i.e.:
    - Coefficient of Determination (R^2) > 0.75
    - Coefficient of Variation (CV(RMSE)) < 0.25
    - Mean Bias Error (MBE) < 0.005%
    - t-statistic of the coefficients > 2
    - Model Coefficients > 0
- The post implementation period occurs as soon as possible after the baseline period
- Savings and associated accuracy are calculated and reported at a 95% confidence level
    - E.g. 234,000kWh +/- 11% @ 95% confidence

The output from each assessment includes a chart depicted at the commencement of each Case Study (Section 3).