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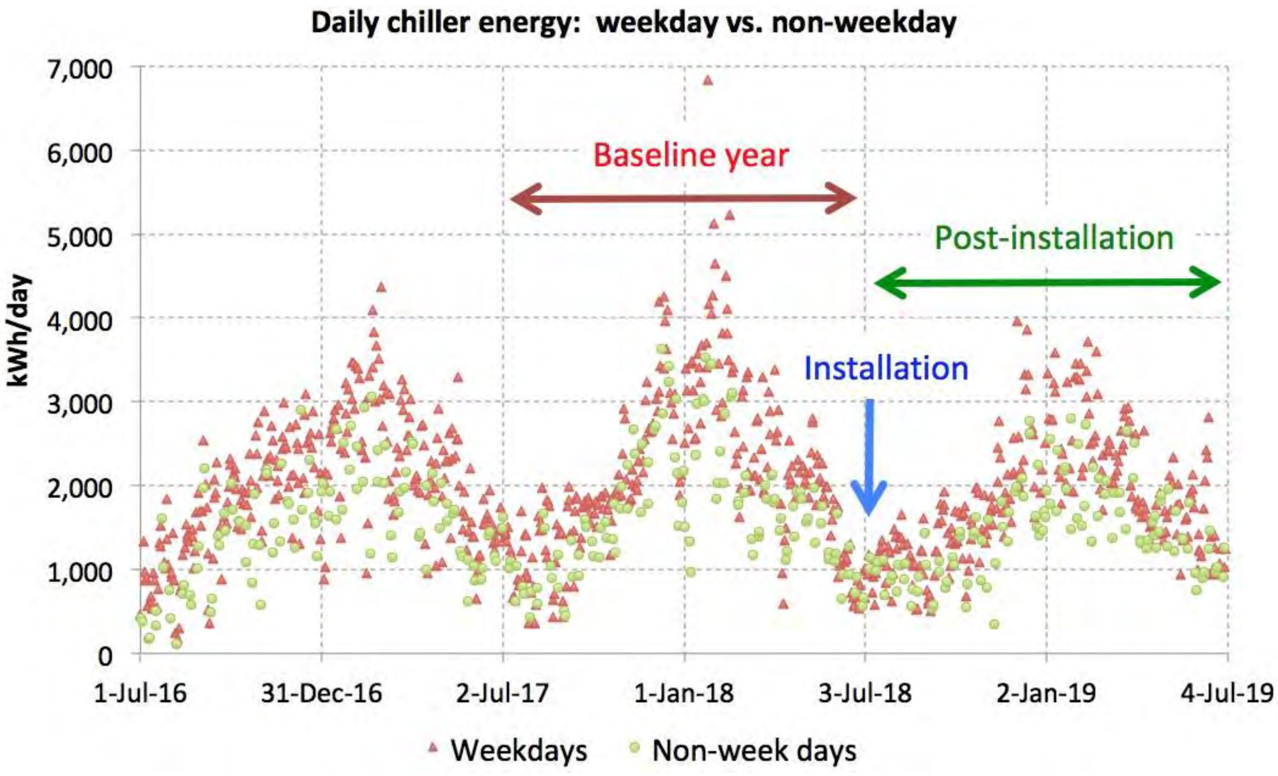
# DeCalon Water Treatment
# Energy Savings Verification – City Gallery

## Executive Summary

In July - September 2018, a “DeCalon” water treatment system was installed on the cooling tower water loop of the Wellington Civic Square cooling system.

This report compares the performance of that cooling system between the 2017-18 summer (baseline year), and the 2018-19 summer (post-installation year) to identify the differences in energy and water consumption, presumably caused by the equipment.

The following graph shows the measured daily chiller electric energy consumption from July 2016 through July 2019. Working days (weekdays) are shown as red triangles, and non-working days (weekends and public holidays) are shown as green circles.




There was a significant reduction in electric energy consumption by the chillers between the baseline and post-installation years.

The total measured reduction was 93,000 kWh/yr (13% of baseline) ± 15,000 kWh/yr (16% of savings, 2% of baseline).

Also there was an apparent reduction in cooling tower fan energy consumption of about 4,000 kWh/yr, and an apparent decrease in water consumption of about 50% (30 cubic metres per day to 15 cubic metres per day).

No confidence intervals are expressed for the two apparent reductions, because the cooling tower energy reduction was less than the uncertainty of the chiller estimate, and the reduction in water consumption was obscured by ongoing overflow issues with the towers.

## Introduction

The Wellington Civic Square cooling plant consists of five electric chillers and four cooling towers with individually controlled fans. Each chiller and tower fan was metered separately (as well as primary, secondary and condenser pumps).

Electricity consumption to the Civic Square chillers, cooling towers and associated pumps was recorded half-hourly into remote-reading submeters from 2016. The data is available on the EnergyICT web page, managed in New Zealand by Energy Solutions Providers (a company unrelated to Energy Solutions Ltd.).

According to 2Plus, the installation of the DeCalon DCI-15A and Biofume was installed and commissioned by 7 September 2018, followed by several weeks of monitoring.

Because the chillers and towers are used interchangeably, the sum of daily electric energy consumed by the five chillers was analysed.

The baseline was calculated as the sum of the five Civic Square chillers' daily metered electric energy (kWh/day) consumption, as a function of the daily average temperature (°C, drybulb) recorded at Kelburn Met Office, and reported by NIWA. The daily data were separated into working day and non-working day. Non-working days were defined as weekend days, or public holidays.

Energy and temperature data were examined from 1 July 2016 through 2 July 2019. The baseline was calculated based on the financial year 1 July 2017 – 30 June 2018. Post-installation was defined as the year 1 July 2018 – 30 June 2019.

The DeCalon systems also claim that less water is consumed by cooling towers. The only data on cooling tower water consumption came from intermittent manual readings recorded by Sandy Winterton between 16 April 2018 and 17 May 2019.

The Central Administration Building (CAB) closed in December 2016, and the Central Library closed on 19 March 2019, though HVAC services were continued at the Library even though it was unoccupied.

The results of this analysis are:

732,888 kWh/yr = Total metered chiller consumption 2017-18

712,158 kWh/yr = Baseline model consumption 2018-19

619,535 kWh/yr = Total metered chiller consumption 2018-19

92,623 kWh/yr (13% of baseline) = Reduced electric consumption

±14,533 kWh (16% of savings, 2% of baseline) = uncertainty in savings, at 90% confidence

Also, there appears to be a reduction in cooling tower fan energy, of about 4,000 kWh last year. This is within the uncertainty of the chiller savings estimate, so it is not calculated in detail.

Likewise, the water consumption of the cooling towers appeared to drop by about 50%. However, due to ongoing overflow issues, the actual consumption before the installation is difficult to clearly determine.

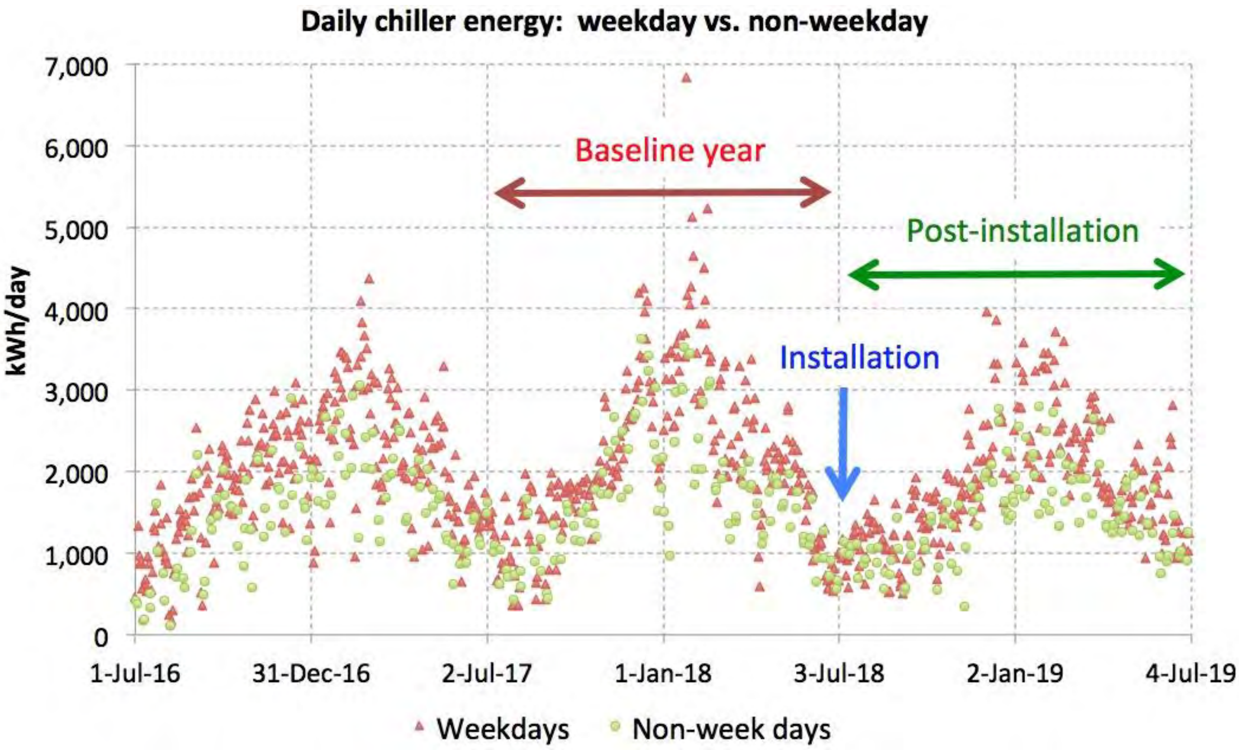
## Calculation of chiller baseline and energy savings

Savings calculations were done according to the IPMVP “Option B” which uses dedicated sub-meters. This greatly improves the accuracy of the predictions compared to other options, as it avoids having the energy consumption for the use in question obscured by mixing with other uses.

Three years of data were analysed, from 1 July 2016 through 2 July 2019. The “baseline” year was taken as 1 July 2017 through 30 June 2018, and the year for analysis was 1 July 2018 through 30 June 2019.

Although the commissioning of the improvements was completed in September 2018, a significant performance increase in the chillers was observed in late June 2018.

In an effort to improve the resolution of the data, it was separated into weekday and weekend (including statutory holiday) days. The daily consumption over this period is shown in the following graph.

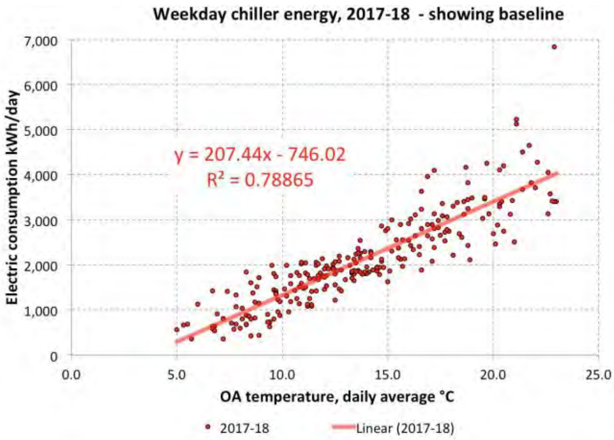


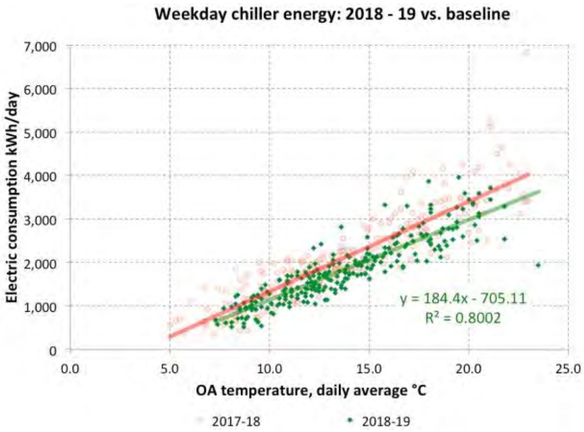

Working day (weekday) consumption is shown as red triangles, and non-weekday consumption is shown as green circles. Non-weekday consumption is generally lower than weekday, though there is considerable overlap. In both cases, the peak consumption days are mid-summer, when outdoor temperatures and cooling loads are highest.

Simple linear regressions were performed on the data, as shown below. These are done separately for weekdays and non-weekdays, separately for each (Council financial) year.

The regressions analyse the daily electric energy consumption vs. daily average outdoor air temperature (as recorded at the Kelburn Met office).

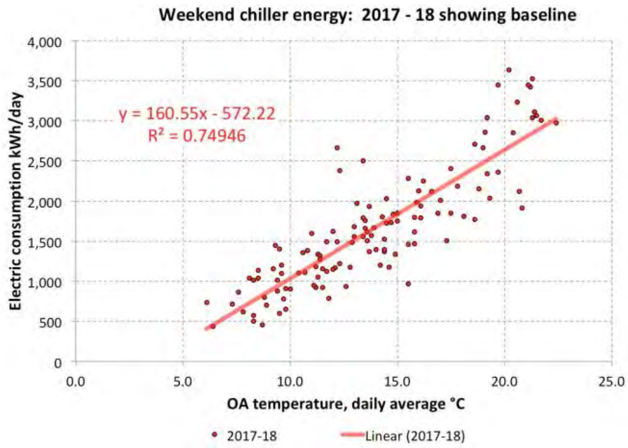
The graph on the left below is for the 2017-18 year. Individual days are shown as dark red points with the best-fit line shown. The graph on the right shows the data for the 2018-19 year as green points, with the best-fit line shown in green. The regression line from 2017-18 is shown in red.

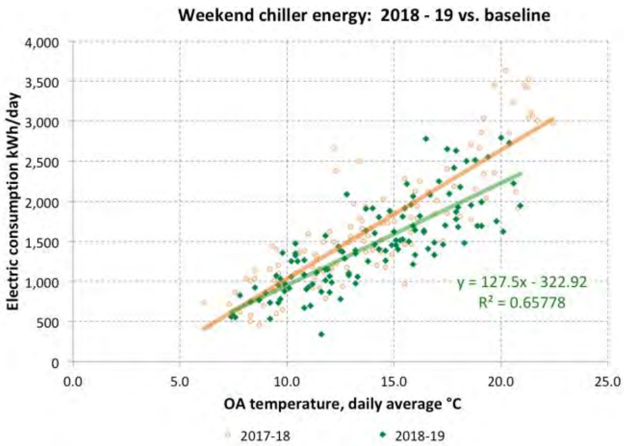



The graph on the left shows a good correlation, with an $R^2$ of almost 0.80. The graph on the right shows a reduction, as the green line is below the red line, as are most of the green points. The regression equation shown in the left graph represents the baseline equation for weekdays.

The same exercise was repeated for weekend data, as shown in the following two graphs.



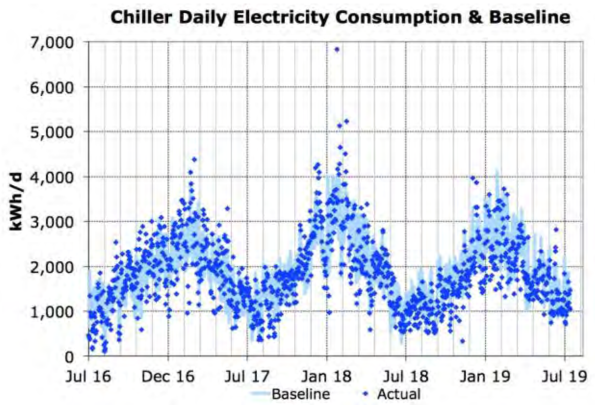



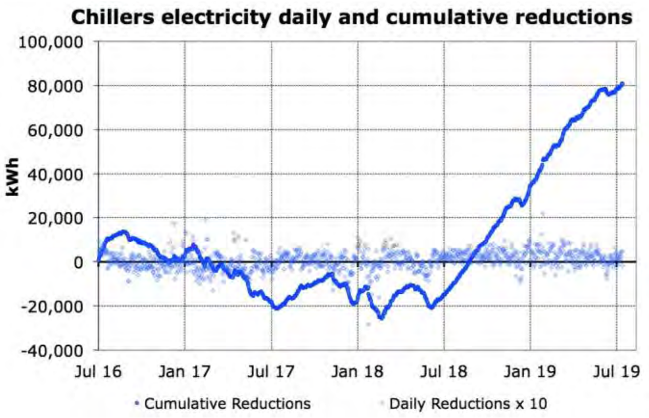

Again the daily data for the 2017-18 year also shows a good correlation, with an $R^2$ of 0.75. And again, the 2018-19 year shows most of the days' electric energy consumption lower than the previous year.

To check for changes over time, the data for the three years was plotted as a time series compared to the baseline. The baseline is defined by the equation of the best-fit curve for the 2017-18 year, for each day-type, based on measured daily average temperature.

The left graph below shows the daily baseline calculated based on each day's actual measured temperature as the light blue line, and the actual consumption for each day as the dark blue point.

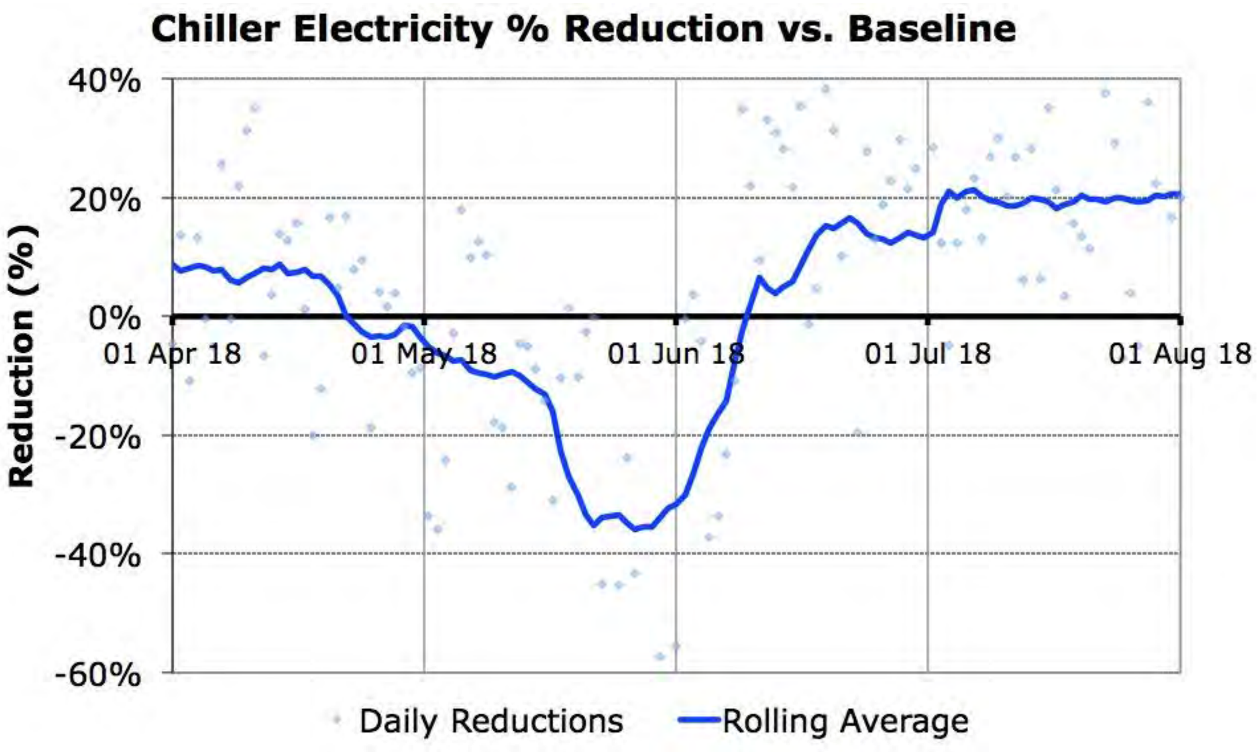
As can be seen, before July 2018 the data tracked the baseline closely, but after then, the consumption dropped visibly – the dark blue points were generally below the light blue line.




The graph on the right above shows the cumulative difference between the baseline and actual consumption as the solid dark blue line, and the daily reductions as the light blue dots (multiplied by 10 for better visibility). From about July 2018, the blue line turned upwards and the daily reductions compared to the baseline were almost always positive.

To confirm that 1 July 2018 was the appropriate time to change from baseline to post-installation analysis, the slope of the Cusum curve shown above was plotted for two months before and after that date. A positive value of slope (shown here as % reduction from baseline) corresponds to the CUSUM curve sloping upward, which would be expected after the improvements were made to the chiller.



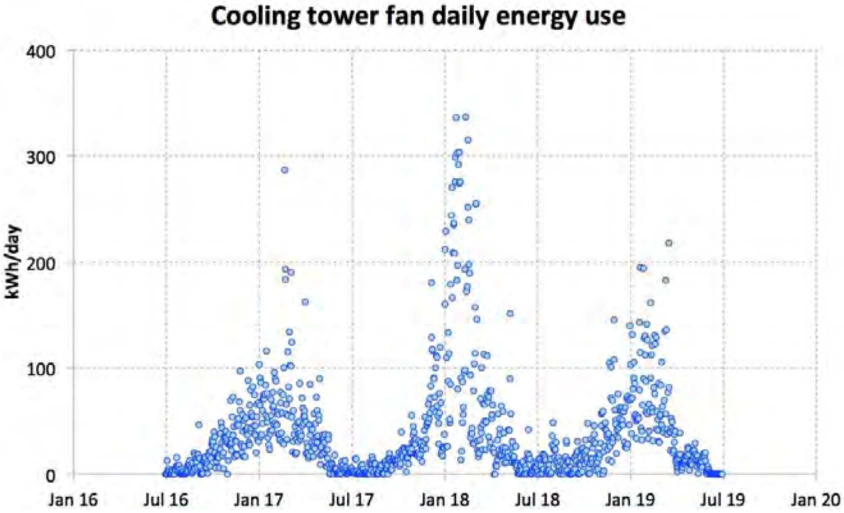

As can be seen, the chiller performance improved from about 30% worse than baseline in May and early June 2018, to about 20% better than baseline in late June.

This significant performance improvement at this time justified using the end of financial year as the point to shift to counting savings.

## Cooling tower performance

The DeCalon literature notes that there can also be reductions in cooling tower fan energy, depending on the control of the condenser water return temperature. Accordingly, the cooling tower energy was also analysed to determine if there were visible, significant reductions.

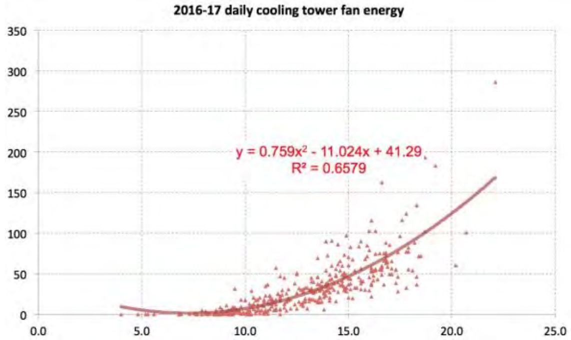
The following graph shows the sum of the four cooling tower fans' daily consumption, for the period 2016-2019, the same time frame as the chiller data which was analysed.

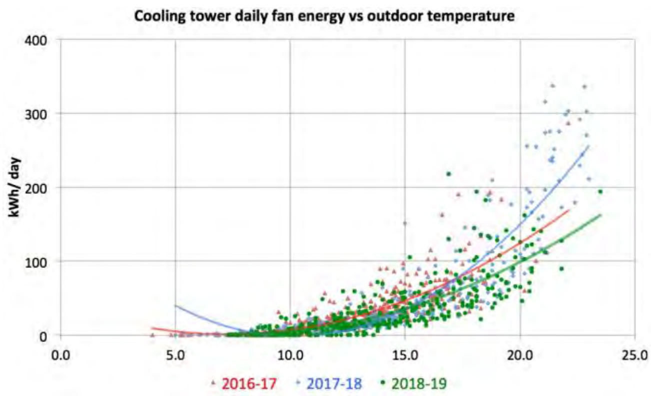



The data peaks in mid-summer, during the time of the highest cooling load. This is due to the need for more cooling tower fan power during peak conditions, to control the temperature of the water returning to the chillers.

Note the unusually high consumption during the early months of 2018 – about double the peaks of the other two years. This was when Wellington experienced several of its warmest days ever. It is likely that the cooling towers were operated harder than intended during that time, to increase chiller cooling capacity.

Tower fan performance was also analysed versus outdoor temperature, the same as was done for the chillers. However, this did not show a linear relationship, with much more fan power on warmer days than cooler ones, and almost none on days with temperatures lower than 9°C, as shown in the graph below left, with the red points and line representing the 2016-17 year.



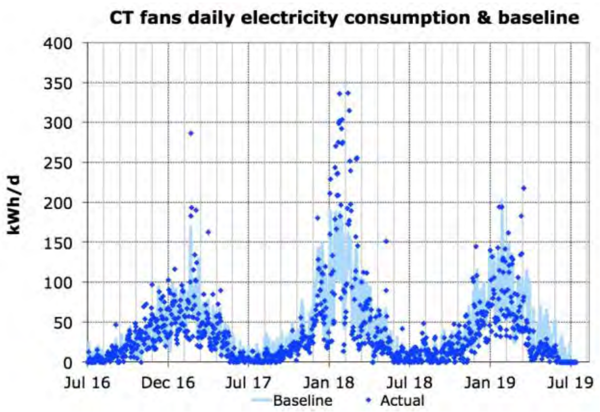



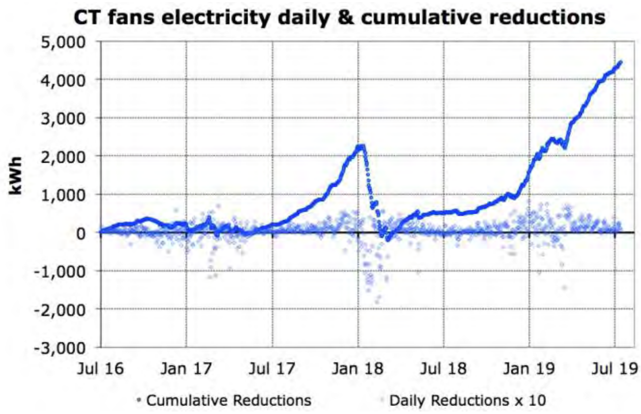
All three years are shown against each other in the graph to the right. The blue line shows the 2017-18 year, which is much higher than the red line (due to the excess summer operation, discussed above), and the green line shows the 2018-19 year, post-installation of the DeCalon system.

As a test, a baseline was constructed using the best-fit equation from the left graph, for the 2016-17 year, then the succeeding years' performance was plotted against that. The following graphs show the results of this exercise.

The graph on the left below shows the time series of the ongoing measured daily electric consumption of the cooling tower fans as dark blue points, compared to the calculated baseline, (for 2016-17, using the formula on the graph above left).

For the first two years, the points generally track the baseline, with summer peaks well above the expected baseline, especially in early 2018. For 2018-19, the consumption is consistently below the baseline, with only a few days above.




The graph on the right above shows the cumulative difference between the baseline and actual consumption as the solid dark blue line, and the daily reductions as the light blue dots (multiplied by 10 for better visibility).

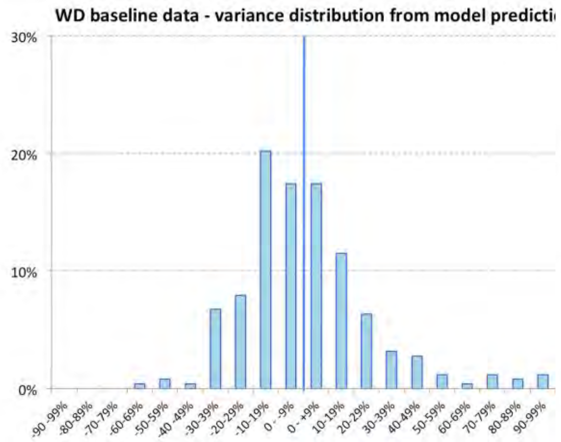
This showed improvement from about July 2017, with a cumulative 2,000 kWh reduction observed by early January 2018. Then, the high consumption during the hot weather cancelled out those savings, with a net change of about zero by March 2018. Then, there was a small, slow increase until about September 2018, and a large increase since then.

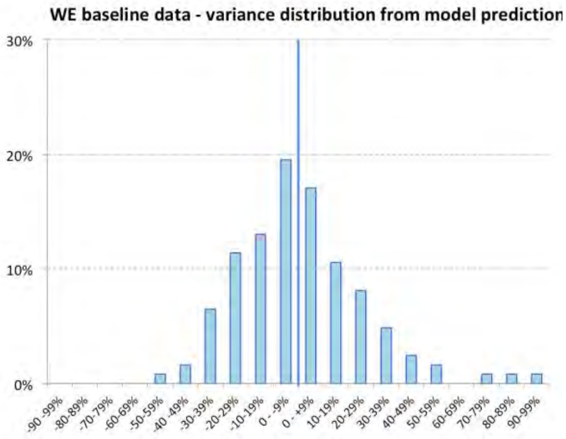
Note that the timing of the increase in savings was about the same time as the installation was commissioned. Although we don't have information on the control of the cooling tower fans, this alignment supports that there were actually improvements in cooling tower performance as well as from the chillers.

The right-hand graph shows a cumulative reduction of about 4,000 kWh from 1 July 2018.

## Data quality

To give an accurate baseline, the data should describe a normal distribution (bell curve), in terms of its distribution around the chosen baseline. To test this, the weekday and non-weekday chiller data was compared to the baseline, and the difference in percent calculated for each data point. Then histograms were developed showing the range of variance from the baseline, in 10% increments. The result is plotted below.




As can be seen, both datasets closely represent normal bell-curve distributions, so the baselines are valid representations of the data sets.

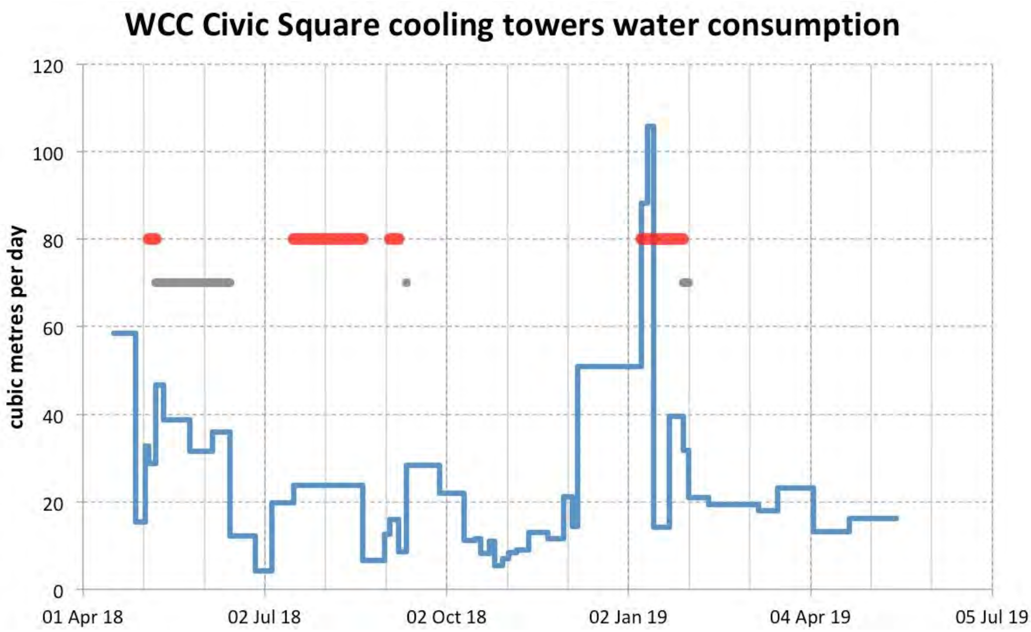
## Water consumption

The DeCalon literature indicates that cooling tower using this system require much less “blow-down” or water drained from the towers’ water reservoir to keep the salt concentrations acceptably low.

This appeared to be the case, but the towers showed a continual problem with over flowing, with excessive water consumption both before and after the DeCalon installation.

The cooling tower water meters were intermittently recorded by Sandy Winterton before he departed, and the data are presented in the graph below.

In each case, the water consumption between readings is averaged over the time interval between readings, so each plateau on the graph shows the average consumption since the previous reading. The graph also has grey lines, representing the times that Sandy noted “slight overflow” and red lines for the times when he noted “(significant) overflow”.




As can be seen, before the installation of the DeCalon system (nominally July 2018), there was slight overflow noted regularly, and an average consumption of about 30 cubic metres per day. After commissioning was completed (September 2018) water consumption stabilised at about 10 cubic metres per day. At the start of December, it jumped up to about 50, and was over 100 cubic metres per day in early January when Sandy again noted it was overflowing.

Subsequently it stabilised at about 20 cubic metres per day (slightly lower as the cooling season ended in May 2019). This is about half of what was experienced before the installation, but because the data is obscured by the effects of the overflows, the confidence in this analysis is relatively low.

## Water Treatment Reduction

The water treatment for the cooling towers was a total of 4litres of Bioside and 3Litres of Inhibitor per chiller, per week. The installation of the DeCalon unit has reduced the total use of these chemicals.

## Conclusion

After installation of the DeCalon system, there was a reduction in chiller electricity consumption of 93,000 kWh/yr (13% of baseline) ±15,000 kWh/yr (16% of savings, 2% of baseline).

This is based on daily analysis, corrected for temperature, using Option B of the IPMVP.

Also there was an apparent reduction in cooling tower energy consumption of about 4,000 kWh/yr, an apparent decrease in water consumption of about 50% (30 cubic metres per day to 15 cubic metres per day), and a decrease in water treatment chemicals of a total of 832L of Bioside and 624L of Inhibitor per annum.