Measurement & Verification Report

Laboratory Refrigeration Units (non ultra-low-Temperature)

# Project Summary

In the Spring of 2021, 35 aging and inefficient laboratory refrigeration units (non-ultra-low-temperature/-20°C) were replaced with 32 new units, funded by the Salix Public Sector Decarbonisation Scheme (PSDS). The project saw a significant impact on the energy consumption of the units themselves in addition to improvement in the heat loss into the buildings, therefore improving comfort levels and reducing the energy consumption of laboratory cooling. There were no planned changes to the baseline in terms of temperature settings or opening hours (compared to a pre-covid baseline).

This M&V Report is based on the principals of measurement and verification outlined in the International Performance Measurement and Verification Protocol (IMPVP) Volume 1, EVO 10000 –1:2012 as detailed in Table 1 below.

The replacement of these 35 units has resulted in energy savings of 9,084.18 kWh per year (35.18%) with an annual cost saving of £1,380.80 and a payback period of 19.71 years. 2.12 tonnes CO2e per year savings have also been calculated. These findings compare favourably with the estimations outlined in our original Salix application evidence pack in terms of estimating the baseline consumption, however the replacement units saved marginally less than the predicted 14,663 kWh, due in part to the effects of increased heating requirement on removal of the inefficient units, the fact that several replacements were not like-for-like in terms of temperature set points and capacity, and the number of non-functional units replaced.

Table : M&V Summary

|  |  |
| --- | --- |
| Framework | |
| M&V plan | Project UoR101d Laboratory Refrigeration Units (non-ULT) M&V Plan (dated February 2021) |
| IPMVP Option | Option A (Retrofit Isolation) |
| Measurement | |
| Measurement Method | Measurable Energy (m.e) plug in energy monitoring platform |
| Measurement Boundary | Refrigeration units subject to the retrofit project |
| Monitoring Period | 1 week for both baseline and verification activities |
| Analysis | |
| Savings Determination | Avoided demand |
| Basis of Routine Adjustments | None |
| Target Uncertainty | Total quantifiable accuracy of the savings +/- 7.07% |
| Reporting | |
| Reporting Schedule (if any major deviations from existing savings are predicted) | Year 0 Report – Immediately following ECM completion.  Repeat measurements could be taken in subsequent years, however for a straightforward equipment replacement project, this is felt to be unnecessary, as results are unlikely to change. |

# 1 Facility Consumption Summary

The following section presents the summary energy consumption data. Measured data were collected for the baseline/pre-retrofit over a period of 1 week between 1st March 2021 and 7th March 2021, which represents a full operational cycle of the ECM. The reporting period data were gathered, also for one week, between 19th April 2021 and 25th April 2021. There were no deviations from the M&V plan and no power outages or data gaps.

Data were gathered for 42.86% of the baseline population and 42.86% of the post-retrofit population. No baseline period adjustment was required; There are no independent variables as energy consumption of the pre-retrofit units were unaffected by the stored load i.e., the volume of samples placed into the units, as they run constantly over 24 hours, and the pre- and post-retrofit operations were not found to differ with respect to door-openings. Similarly, no adjustment for static factors was required as during spot checks on operational usage in terms of thermostat settings; the units remained at the same settings and operating patterns throughout the monitoring periods (most are long-term sample storage with minimal daily use).

1. **Baseline period adjustment data**

## Independent Variables/Routine Adjustments

No adjustment required.

## Baseline Static Factors

No adjustment required.

## Adjustments for Interactive Effects

Only the refrigeration units are measured, however, the retrofit has an interactive effect in terms of reducing the amount of excess heat leaked into the environment by the inefficient refrigeration units in the retrofitted areas. The reduction of space heat gain: a) increases the heating required in the winter, and b) decreases the cooling required in summer. These interactive effects only occur in the retrofitted spaces which are temperature controlled by the plant’s heating and cooling system.

Calculation methodology for determining the adjustments required from changes to the heating and cooling of the laboratories are detailed in Section 5D of the associated M&V plan. These calculations are based on the heating and cooling months and the efficiencies of the heating and cooling systems, the results of which are detailed in Table 2 below. Where laboratories are connected to the district heating system (e.g., Chemistry Department), the heating efficiency is reported at 55.73% for the combined heat and power (CHP) engine. However, it should be noted that this is not a full picture of the efficiency of the system as the power efficiency is 23.77% and the combined overall efficiency is 79.5%.

Table : Adjustments for interactive effects

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Unit | Location | Coefficient of Performance (COP) (Air Conditioning Units) | Annual additional cooling energy saved (kWh) | Heating efficiency (%) | Annual additional heating energy required (kWh) |
| Freezer Under Counter | Harry Nursten 3.18 | 3.14 | 1.11 | - | - |
| Freezer Under Counter | Harry Nursten 3.18 | 3.14 | 0.66 | - | - |
| Fridge Freezer | Harry Nursten 3.18 | 3.14 | 5.45 | - | - |
| Fridge Freezer | Harry Nursten 3.18 | 3.14 | 1.99 | - | - |
| Fridge Freezer | Harry Nursten 3.18 | 3.14 | 3.72 | - | - |
| Fridge Freezer | Harry Nursten 3.18 | 3.14 | 3.72 | - | - |
| Fridge Freezer | Harry Nursten 3.18 | 3.14 | 3.72 | - | - |
| Fridge Freezer | Hopkins 119 | 4.15 | 2.81 | 70 | 37.33 |
| Fridge Under Counter | Harry Nursten 3.18 | 3.14 | 0.85 | - | - |
| Fridge Under Counter | Harry Nursten 3.18 | 3.14 | 0.76 | - | - |
| Freezer Under Counter | Harry Nursten 3.18 | 3.14 | 3.90 | - | - |
| Fridge Under Counter | Harry Nursten 3.18 | 3.14 | 3.11 | - | - |
| Fridge Under Counter | Chemistry 1.40 | - | - | 55.73 | 10.77 |
| Fridge Under Counter | Hopkins 110 | - | - | 70 | -9.51 |
| Fridge Under Counter | Hopkins 212 | - | - | 70 | 8.47 |
| Fridge Under Counter | Wager 109 | 3.81 | 0.70 | - | - |
| Fridge Under Counter | Russell Teaching 1 | - | - | 84 | 7.05 |
| Fridge Under Counter | Russell 131 | - | - | 84 | 7.05 |
| Tall Freezer | Harry Nursten 1.28 | 3.69 | 1.67 | - | - |
| Tall Freezer | Harry Nursten 3.18 | 3.14 | 7.30 | - | - |
| Tall Freezer | Harry Nursten 3.18 | 3.14 | 11.63 | - | - |
| Tall Freezer | Hopkins 110 | - | - | 70 | 17.74 |
| Tall Freezer | Hopkins 110 | - | - | 70 | 21.74 |
| Tall Freezer | Hopkins 111 | 3.69 | 7.90 | 70 | 93.20 |
| Tall Fridge | Harry Nursten 3.32 | 3.85 | -0.64 | - | - |
| Tall Fridge | Harry Nursten 3.32 | 3.85 | -0.89 | - | - |
| Total |  |  | 59.47 |  | 193.85 |

# Energy Savings Calculations

Table 3 presents the methods for data adjustment according to changes in independent variables and static factors to determine the avoided demand.

Table : Method for baseline adjustment

|  |  |
| --- | --- |
| Retained Option | Equation |
| Avoided demand (kWh) | Avoided Demand =  Baseline demand  ( - )  Reporting period energy  ( ± )  **Routine** adjustments to period conditions  ( ± )  **Non-routine** adjustments to period conditions |

Table 4 provides a summary of the ECM in terms of energy, cost and emissions savings, without adjustment for interactive effects.

Table : ECM Summary

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Location | Baseline Energy Use (kWh) | Reporting period | Energy Savings (kWh) | Energy Savings (%) | Cost Savings (£) | Emissions Savings (kgCO2e) |
| Total (weekly) | 496.58 | 319.30 | 177.28 | 35.70 | 26.95 | 41.33 |
| Total (annual) | 25,822.04 | 16,603.48 | 9,218.57 | 35.70 | 1,401.22 | 2,149.22 |
| Total (annual with adjustment for interactive effects) | 25,822.04 | 16,737.86 | 9,084.18 | 35.18 | 1,380.80 | 2,117.89 |

Table 5 displays the full data from the measurements taken of both the baseline and reporting periods, alongside the consumption savings in terms of kWh, cost and kgCO2e.

As per the M&V plan, electricity consumption costs used for savings calculation (baseline or reporting period) are based on rates effective during the reporting period and were established at 0.152 p/kWh including VAT for electric, and 0.038 p/kWh including VAT for gas. CO2 equivalent (kgCO2e) savings were calculated using the UK Government Department for Business, Energy and Industrial Strategy (BEIS) figures for 2020; 0.23314 kgCO2e per kWh for grid electricity and 0.184 kgCO2e per kWh for grid natural gas. This differs from the Salix Finance conversion factors which take into account persistence factors, however the BEIS nationally available figures is adopted here to ensure consistency with other reporting.

Table : Annual energy (kWh), cost (£) and emissions (kgCO­2e) savings

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Location | Baseline Energy Use (kWh) | Reporting period | Reporting period (with interactive effects) | Energy Savings (kWh) | Energy Savings (%) | Cost Savings (£) | Emissions Savings (kgCO2e) |
| Harry Nursten 3.18 | 653.41 | 528.273 | 527.167 | 126.24 | 19.32 | 19.19 | 29.43 |
| Harry Nursten 3.18 | 523.74 | 448.552 | 447.888 | 75.85 | 14.48 | 11.53 | 17.68 |
| Harry Nursten 3.14 | 573.52 | 488.412 | 488.412 | 85.11 | 14.84 | 12.94 | 19.84 |
| Harry Nursten 3.18 | 865.47 | 248.718 | 243.266 | 622.20 | 71.89 | 94.57 | 145.06 |
| Harry Nursten 3.18 | 506.54 | 281.802 | 279.815 | 226.72 | 44.76 | 34.46 | 52.86 |
| Harry Nursten 3.18 | 686.00 | 265.260 | 261.541 | 424.46 | 61.87 | 64.52 | 98.96 |
| Harry Nursten 3.18 | 686.00 | 265.260 | 261.541 | 424.46 | 61.87 | 64.52 | 98.96 |
| Harry Nursten 3.18 | 686.00 | 265.260 | 261.541 | 424.46 | 61.87 | 64.52 | 98.96 |
| Chemistry 1.69 | 686.00 | 265.260 | 265.260 | 420.74 | 61.33 | 63.95 | 98.09 |
| Hopkins 119 | 686.00 | 265.260 | 299.772 | 386.23 | 56.30 | 58.71 | 90.05 |
| Hopkins 114 | 686.00 | 265.260 | 265.260 | 420.74 | 61.33 | 63.95 | 98.09 |
| Tob2 | 686.00 | 265.260 | 265.260 | 420.74 | 61.33 | 63.95 | 98.09 |
| Agriculture GU35 | 686.00 | 1093.338 | 1093.338 | -407.34 | -59.38 | -61.92 | -94.97 |
| Harry Nursten 3.18 | 576.40 | 480.729 | 479.883 | 96.52 | 16.75 | 14.67 | 22.50 |
| Harry Nursten 3.18 | 498.24 | 412.189 | 411.429 | 86.81 | 17.42 | 13.20 | 20.24 |
| Harry Nursten 3.18 | 440.85 | 0.000 | -3.897 | 444.75 | 100.88 | 67.60 | 103.69 |
| Harry Nursten 3.18 | 785.43 | 433.163 | 430.049 | 355.38 | 45.25 | 54.02 | 82.85 |
| Chemistry 1.40 | 528.59 | 433.163 | 443.938 | 84.65 | 16.01 | 12.87 | 19.74 |
| Hopkins 110 | 299.39 | 406.570 | 397.061 | -97.68 | -32.63 | -14.85 | -22.77 |
| Hopkins 212 | 528.59 | 433.163 | 441.629 | 86.96 | 16.45 | 13.22 | 20.27 |
| Wager 109 | 528.59 | 433.163 | 432.468 | 96.12 | 18.18 | 14.61 | 22.41 |
| Russell Teaching 1 | 528.59 | 433.163 | 440.218 | 88.37 | 16.72 | 13.43 | 20.60 |
| Russell 131 | 528.59 | 433.163 | 440.218 | 88.37 | 16.72 | 13.43 | 20.60 |
| Harry Nursten 3.31 | 1315.86 | 1093.338 | 1093.338 | 222.52 | 16.91 | 33.82 | 51.88 |
| Harry Nursten 1.28 | 1315.86 | 1093.338 | 1091.665 | 224.19 | 17.04 | 34.08 | 52.27 |
| Harry Nursten 4.05 | 1315.86 | 1093.338 | 1093.338 | 222.52 | 16.91 | 33.82 | 51.88 |
| Harry Nursten 3.18 | 825.86 | 0.000 | -7.300 | 833.16 | 100.88 | 126.64 | 194.24 |
| Harry Nursten 3.18 | 1315.86 | 0.000 | -11.632 | 1327.49 | 100.88 | 201.78 | 309.49 |
| Harry Nursten 4.05 | 205.13 | 311.270 | 311.270 | -106.14 | -51.74 | -16.13 | -24.75 |
| Hopkins 110 | 1287.75 | 1087.730 | 1105.475 | 182.28 | 14.15 | 27.71 | 42.50 |
| Hopkins 110 | 1343.96 | 1098.947 | 1120.683 | 223.28 | 16.61 | 33.94 | 52.05 |
| Hopkins 111 | 1315.86 | 265.260 | 350.562 | 965.29 | 73.36 | 146.72 | 225.05 |
| Hopkins 210 | 1315.86 | 1093.338 | 1093.338 | 222.52 | 16.91 | 33.82 | 51.88 |
| Harry Nursten 3.32 | 230.60 | 319.134 | 319.772 | -89.17 | -38.67 | -13.55 | -20.79 |
| Harry Nursten 3.32 | 179.65 | 303.405 | 304.297 | -124.65 | -69.38 | -18.95 | -29.06 |
| Total | **25,822.04** | **16,603.48** | **16,737.86** | **9,084.18** | **35.18** | **1,380.80** | **2,117.89** |

1. **Comparison of actual versus predicted savings**

A summary of the energy savings predicted compared with the measured data is displayed in Table 6. The measured data compares very favourably with the predicted data set out in the original Salix grant application. Initial estimations of the annual kWh consumption of the refrigeration units vary by just 3% from the actual measured consumption. The retrofitted, new units consume 27% more electricity than their predicted consumption and this has resulted in a 19.82% decrease in the energy savings verses what was predicted (an additional 5,578 kWh). Consequently, an increased payback period of 19.71 years has been calculated compared with the 13.79 estimated in the original application.

The increased consumption due to interactive effects (increased heating requirements) are an unfortunate consequence to the reduced heat gains into each lab from the much more efficient equipment. Furthermore, several refrigeration units were found to be non-functional during the baseline period. For example, the two tall refrigerators in Harry Nursten lab 3.32 did not have functional compressors and were only consuming when the door was opened (due to the internal lighting). Therefore, consumption in this lab was increased from 410.26 kWh to 622.54 kWh per year upon retrofit. Similarly, there were several examples of smaller appliances being replaced with larger or higher consuming units. In one case, the replacement of a 13.19 kWh per week fridge-freezer with a 406l tall freezer consumed 59% more energy in the Agriculture GU35 laboratory. However, there exist a number of co-benefits in addition to the significant 35% overall energy reduction from this ECM. The retrofit has resulted in a more comfortable working environment for occupants, greater operational control of appliances and sample storage, and the overall storage space has been increased despite an overall reduction of 3 units. Mention must also be made of the removal of a number of 25-year-old units utilising high global-warming-potential refrigerants. While the impacts of these refrigerants cannot be determined without full maintenance records to facilitate the calculation of fugitive emissions due to refrigerant leakage, these will almost certainly not be negligible within the positive benefits of completing this ECM.

Table : Energy conservation measure projected savings

|  |  |  |
| --- | --- | --- |
| Calculation | Updated Salix Application | Actual |
| Annual kWh Pre-Project | 26,760 | 25,822.04 |
| Annual kWh Post-Project | 12,097 | 16,737.86 |
| Annual Savings (kWh) | 14,663 | 9,084.18 |
| Annual Savings (% kWh) | 55% | 35.18% |
| Project Cost (£) | £30,750 | £27,219.60 |
| Annual Financial Savings (£) | £2,229 | £1,380.80 |
| Payback (Years) | 13.79 | 19.71 |
| tCO2e Pa | 3.7 | 2.12 |