Energy Consumption Analysis for

Scottish Borders Council Headquarters

Friday, 20 December 2019

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1.0 Summary

1.1 ABSTRACT

The purpose of this report is to analyse the gas data provided by the Scottish Borders Council (SBC) for before and after the installation of the Genius Hub system, to determine the energy saved as a result. This report is a continuation of the analysis previously carried out 4 weeks after the initial Genius Hub Installation at SBC Head Quarters. This analysis has been carried out over a whole year and thus provides more conclusive findings.

This report found an average saving of 21% since the installation of the Genius Hub system in April 2018. An additional 12% + 9% saving (totalling 42%) could be potentially achieved by controlling the boilers and pumps together, where as currently the Genius Hub is only controlling the main circulation pumps and the individual rooms.

1.2 PROJECT OUTLINE

The Scottish Borders Council (SBC) Head Quarters, based in St Boswells South East Scotland, provides an excellent example of a well-maintained and busy council office, accommodating around 60 members of staff. The offices are in good condition overall and it was chosen for this pilot because it was a building with high energy consumption, and because it was difficult to apply any additional energy saving measures to the building due to its age, construction and available budget. The rooms comprise of open plan office space, cellular offices, meeting rooms, council chambers and communal meting spaces. SBC were looking for a low cost and effective energy saving measure that could be easily retrofitted to the buildings from the SBC estate with little or no disruption to the occupants of the building.

1.3 FUTURE PROJECTS

The purpose of running a pilot project was to assess whether the Genius Hub system lives up to the expectations of its ease of use and energy savings. Success in these fields will lead to contracts for other buildings of the SBC's estate which have problems with:

- High energy costs
- Overheating and Underheating
- Lack of visibility of heating problems
- Existing heating systems being run for too long and causing maintenance problems

1.4 PERIOD OF ANALYSIS

The relevant dates for this project are:

- 01/01/17 - Gas data analysis starts
- 26/06/17 -> 11/09/17 - Boilers turned off for the summer
- 04/04/18 - Initial Genius Hub Installation
- 09/04/18 - Running on Timer Mode
    - One week where the system was in timer mode and set to be on at exactly the same time as the previous time clocks.
- 16/04/18 onwards - Running in Footprint mode
    - Where the system automatically reacts to when the rooms are being used with no loss of comfort.
- 11/06/18 -> 03/09/18 - Boilers turned off for the summer
- 03/09/18 onward - Running in Footprint mode
    - Minor modification made to the program for the Chambers Rooms as these are under-radiatored, to bring the heating on during the night, otherwise all rooms running on standard Footprint settings.
- 30/04/2019 - End of analysis

The gas data from January 2017 -> March 2018 (pre-install) has been compared with gas data from April 2018 -> April 2019 (post-install).

2.0 Analysis

2.1 METHODOLOGY

Explanation of degree days

The ‘kWh / Degree Day °C’ has been used as a way of comparing concurrent months in a calendar year while taking into account fluctuations in external temperature. Like 'miles per gallon', but where the type of road and driving conditions have been standardised.

Degree days are used to normalise the energy consumption of a building against fluctuations in external temperatures. The outside temperature changes day to day, month to month and to compare one month to the next or one year to the next, degree days analysis is widely accepted as the proven method to compare the heating energy usage of buildings by reducing the effect of the variable external temperature as much as is possible.

The average internal temperature of a centrally heated home is 17.4°C (ONS Energy Consumption in the UK 2017 Update). Generally, a Degree Day Base Temperature of 15.5° is chosen. The average temperature takes into account the times of the day that the home is not heated which on average is less during the week but more at the weekends. This is the opposite of a workplace environment which is generally heated more during the week and less during the weekend. For most buildings, homes or offices it is widely accepted that the internal heat gain is 3°C.

Though there are no official regulations for workplace temperature, it has been assumed that the internal temperature needs to be 21-22°C for comfort levels. In accommodation type environments, lower internal temperatures can be used (19-20°C). By normalising the energy use against the Degree Day Temperature this gives a comparative fuel use (kWh/°C) which in theory should be the same regardless of external temperature (i.e. the amount of kWh used should be directly proportional to the external temperature). However, in practice external factors disrupt this relationship.

A technique called Linear Regression Analysis can be used to select the best Base Temperature specifically for the building in question. This is not an exact science; the comfort of the occupants of the building and the building’s usage contribute significantly to the real Base Temperature. However, the reason for calculating this is to establish at what (external) temperature that it can be assumed that no heating is required to maintain an acceptable comfort level for the users of the building. This is used to confirm the 'Base Temperature' selected for the building.

Linear Regression Analysis has been carried out for the property using data from 04/2018 -> 04/2019 and a best fit line was plotted against the Heating Degree Days (HDD) and energy usage (kWh) to give a 'best guess' of the correct base temperature. This is not an exact science as solar gain, the comfort of the occupants of the building and the usage of the building also pay a large role in the correct base temperature to be selected. However the reason for calculating this is to establish at what (external) temperature that it can be assumed that no heating is required to maintain an acceptable comfort level for the users of the building.

In the last report, two weather stations were compared for this analysis, Eskdalemuir SCT, and Charterhall. Eskdalemuir SCT was selected to provide the weather data for the Degree Day analysis and will be used in this run of analysis.

	Weekely Total Degree Days (12.5º days)	Weekely Total Degree Days (13º days)	Weekely Total Degree Days (13.5º days)	Weekely Total Degree Days (14º days)	Weekely Total Degree Days (14.5º days)	Weekely Total Degree Days (15º days)
Gradient	52.262	51.322	50.420	49.643	48.952	48.365
Intercept	699.5	578.7	459.4	337.5	214.1	86.1
R2	0.828	0.833	0.837	0.839	0.841	0.841

Weekely Total Degree Days (15.5º days)	Weekely Total Degree Days (16º days)	Weekely Total Degree Days (16.5º days)	Weekely Total Degree Days (17º days)	Weekely Total Degree Days (17.5º days)	Weekely Total Degree Days (18º days)	Weekely Total Degree Days (18.5º days)
47.922	47.425	47.054	46.709	46.415	46.109	45.894
-48.7	-176.8	-311.9	-447.1	-583.8	-718.3	-859.4
0.842	0.841	0.841	0.840	0.840	0.838	0.838

Figure 1 *– Table showing the gradient, intercept & R^2 value of each Degree Day Data set (12.5-18.5°C) when as a function of gas usage.*

An R^2 above 0.9 shows a strongly correlating data set.

Using the Linear Regression Analysis, a base temperature of 15.5° was selected for the data analysis as this held the highest R^2 for 2018 -> 2019.

We present our findings in terms of both:

- Consumption vs Time, which plots the normalised energy consumption to track the energy consumption through long periods of time and to compare the energy usage before and after installation.
- Consumption vs Heating Degree Days, which analyses the efficiency of the heating control by calculating the normalised energy consumption's line of best fit.

2.2 THE DATA

Data set 1, the data previously provided to Genius Hub for the period January 2017 -> May 2018, gave half-hourly readings.

Data set 2, the data most recently provided to Genius Hub for the period January 2018 -> March 2019, gave daily readings.

Both data sets were utilised in this report's analysis.

2.3 BEFORE GENIUS HUB INSTALLATION

When the external temperature drops the building is underheated and when it is warmer the building overheats.

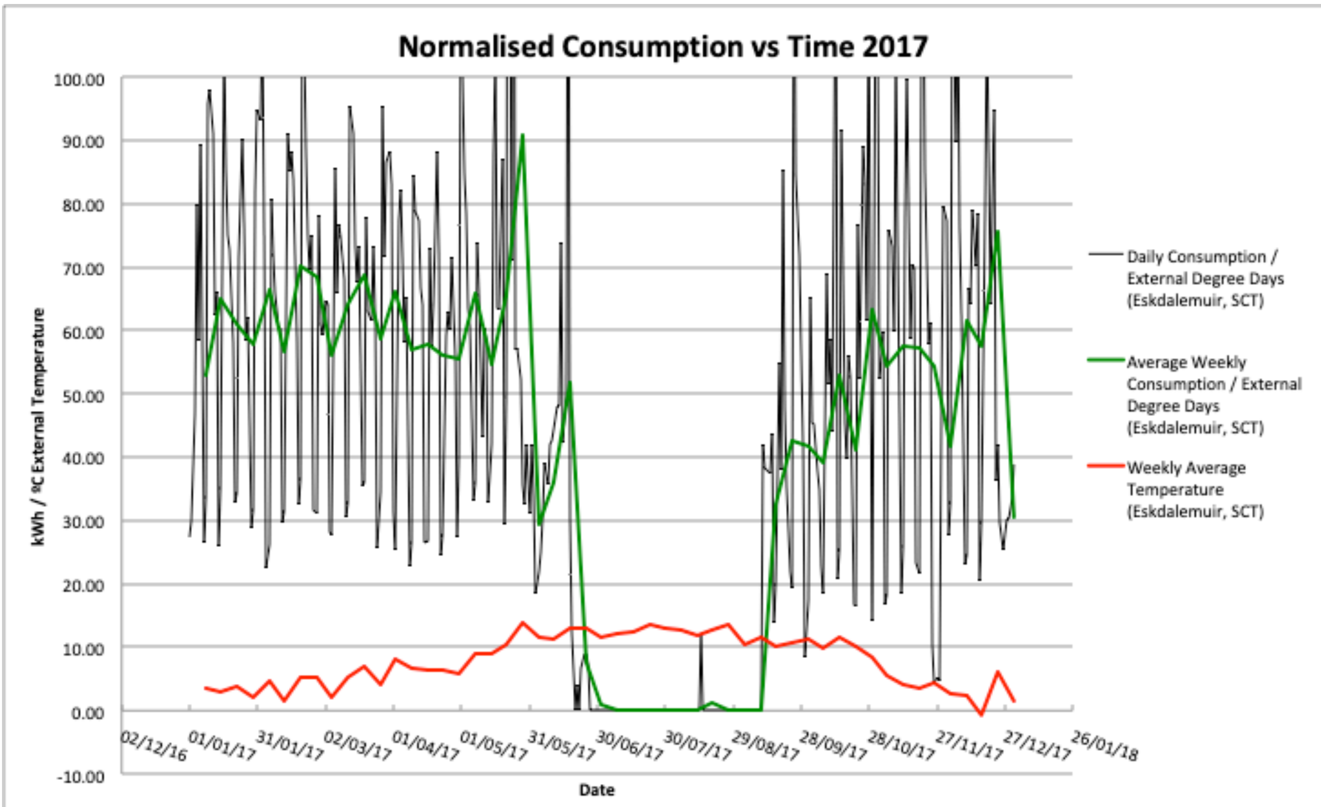


Figure 2 *– Graph showing Normalised Consumption vs Time (2017). The external temperature is shown in red.*

Figure 2 shows that the 'Average Weekly Consumption', which has been normalised against Heating Degree Days, runs parallel with the 'Weekly Average Temperature'. This is a sign of overheating and under heating as the building becomes less efficient on days that it is warmer outside because of rooms being overheated and people opening windows etc. or the system is generally undersized so consumption is 'capped' by the maximum output of the boiler.

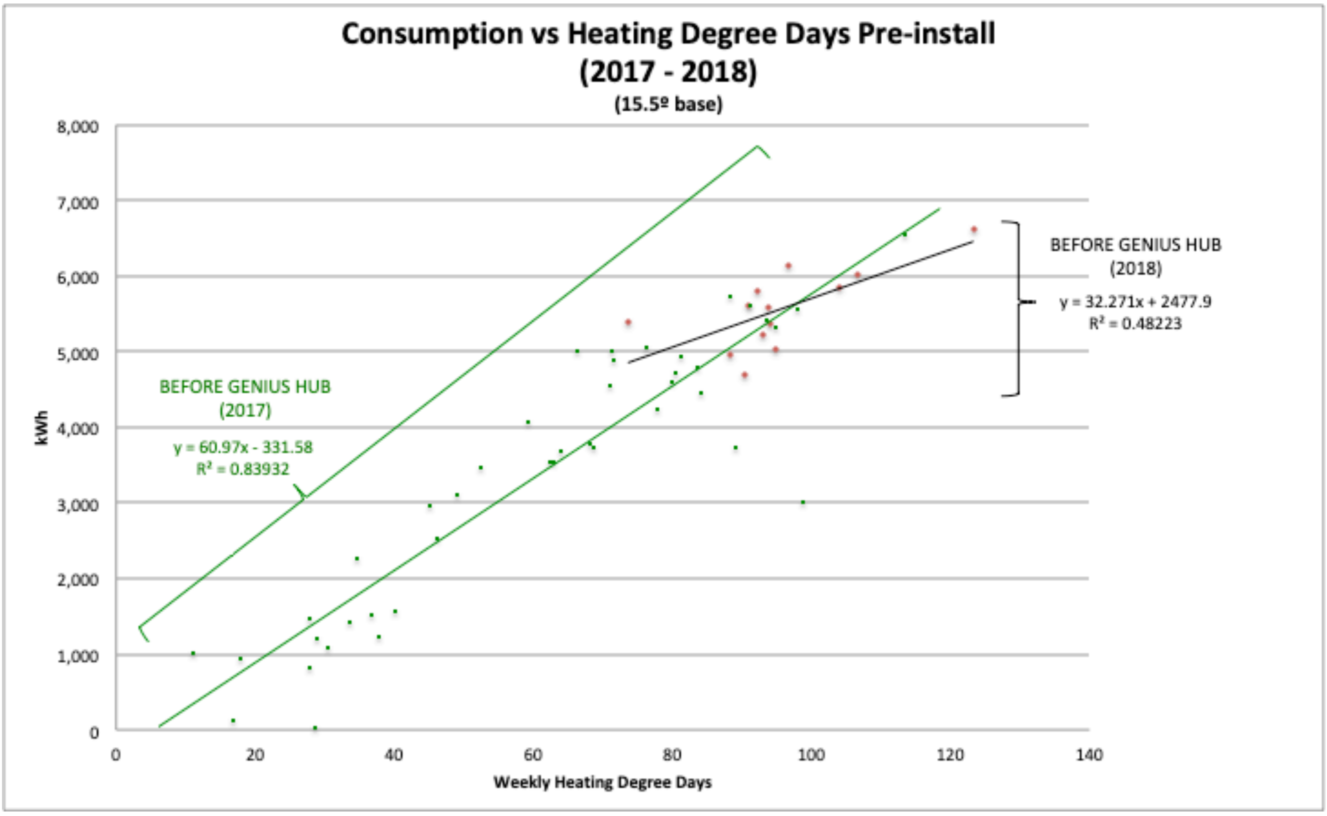


Figure 3 *– Graph showing energy consumption per weekly heating degree days prior to installation of Genius Hub system (01/01/2017 -> 31/03/2018).*

Figure 3 shows the energy usage as a function of weekly heating degree days pre-installation. Data points tend toward the bottom left hand corner of the plot; less energy is being used to heat a property as external temperature increases.

2.4 AFTER GENIUS HUB INSTALLATION

The energy usage was compared for concurrent months from the point that the Genius Hub system was installed (04/04/2018) to calculate 1 years' total savings. For the majority of months, the Genius system reduced the energy consumption. September experienced a significant increase in energy usage, possibly as a result of when the boilers were turned back on as this was not a complete month.

The savings for each month are compared with the average energy usage for the 16 months preceding the installation of the Genius Hub demonstrating a 21% average saving for the year 18/19 when compared with the 16 months gas usage previously recorded.

Month	Average Energy Usage (kWh/ºC/month)		%age savings compared with average 17/18
	17/18 (**pre**-install)	18/19 (**post**-install)	
April	58.43	50.58	14%
May	69.16	35.97	39%
June	-	-	-
July	-	-	-
August	-	-	-
September	37.63	40.36	31%
October	47.63	45.74	22%
November	55.89	48.37	18%
December	59.10	48.08	18%
January	62.39	43.06	27%
February	58.11	56.29	4%
March	56.91	50.79	14%
Average	56.14		**21%**

Figure 4 *- Month by month breakdown of energy consumption and calculated savings.*

- In 2017/18, the energy consumption falls approximately within the range 37-62 kWh / °C External Temperature.
- In 2018/19, the energy consumption falls approximately within the range 35-56 kWh / °C External Temperature.

Normalised consumption vs time was also plotted to visualise the energy usage over the course of a year. Figure 5 shows energy consumption as a function of time for both before and after the Genius Hub system was installed.

Comparing Figures 2 & 5 (see Figure 6, which augments the two), on first impressions there is clearly a significant difference between April -> May and October -> November for 2017 & 2018.

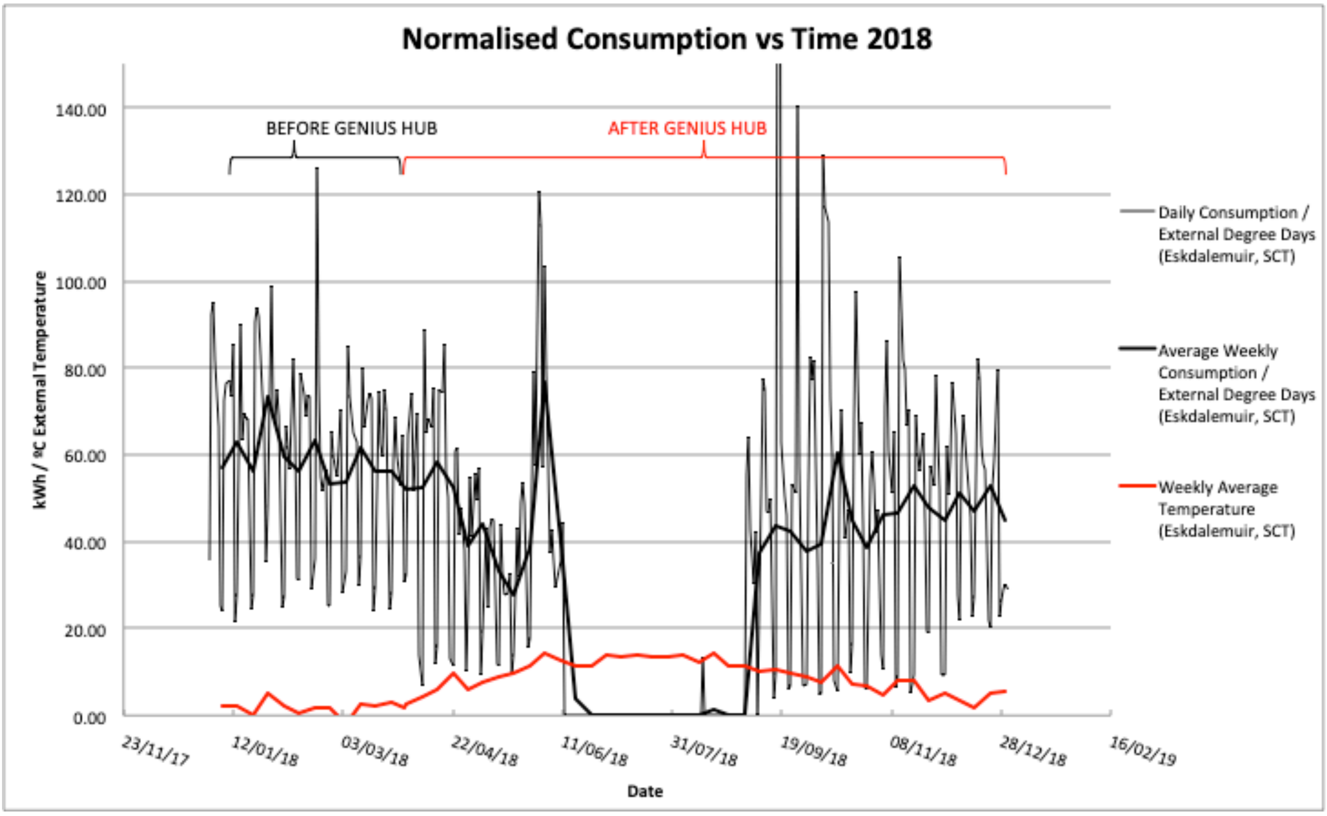


Figure 5 *- Normalised Consumption vs Time (2018).*

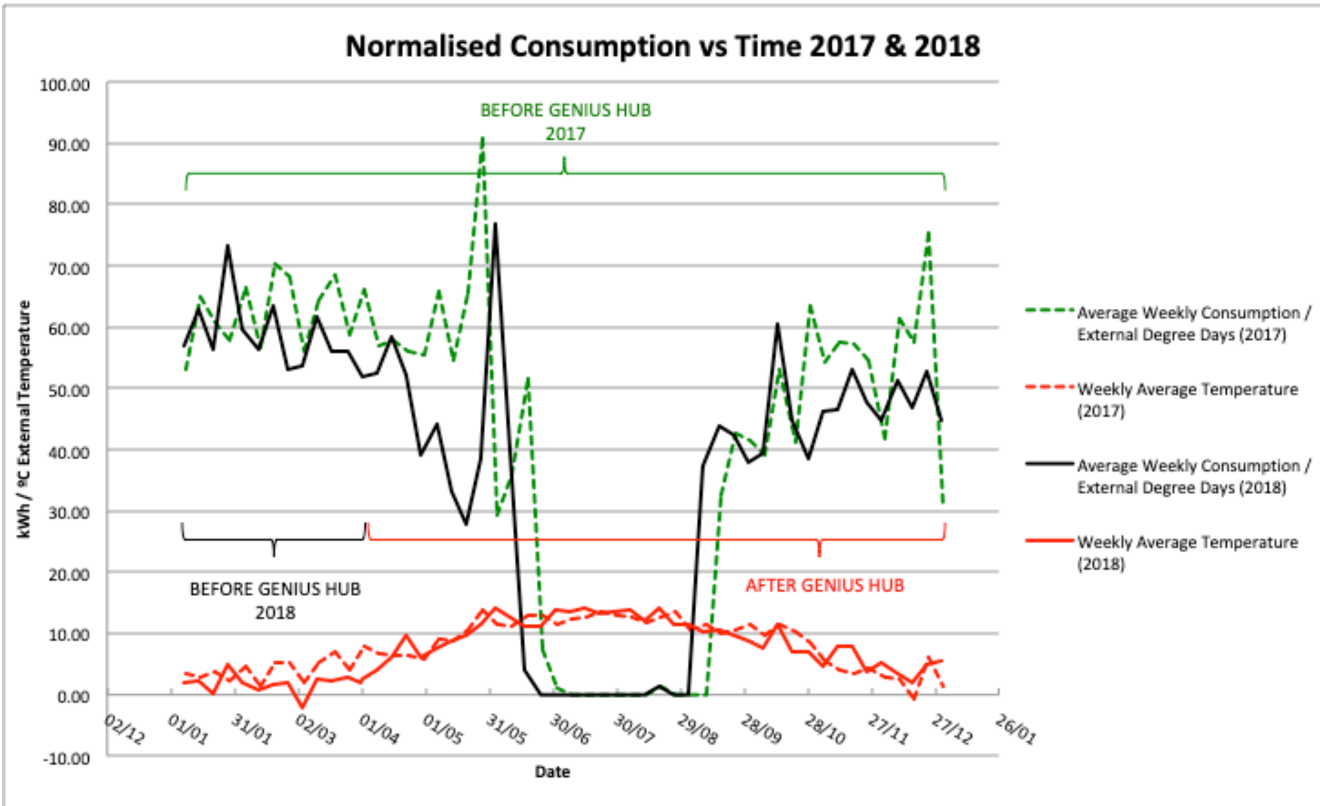


Figure 6 *– Normalised consumption vs Time (2017 & 2018) (Figures 2 & 5 augmented).*

Figure 6 shows the normalised energy consumption over time. The red line shows the average temperature in 2018 was significantly colder than 2017 in the spring (February -> April) where as the black line shows for the same period the normalised consumption decreased, showing that the system was working more efficiently. In the winter of 2017 & 2018 (October -> January) the temperatures were approximately the same and the normalised consumption was also lower in 2018. The only times when the post installation normalised consumption was higher than pre-installation was around the time of the boilers being turned on or off at either end of the heating season, proving that the Genius Hub system has enhanced the efficiency of the heating controls within the property.

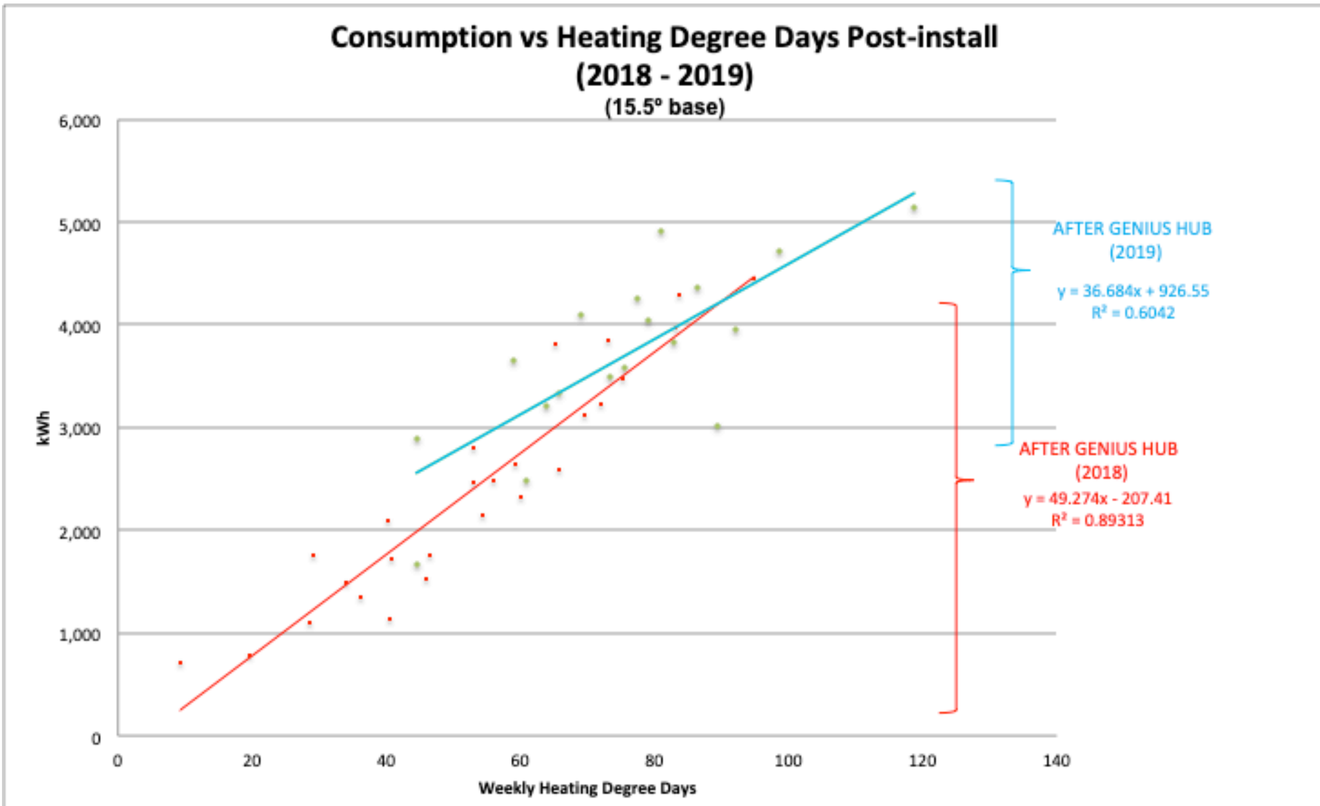


Figure 7 – *Graph showing energy consumption per weekly heating degree days after installation of the Genius Hub system (01/04/2018 -> 01/05/2019).*

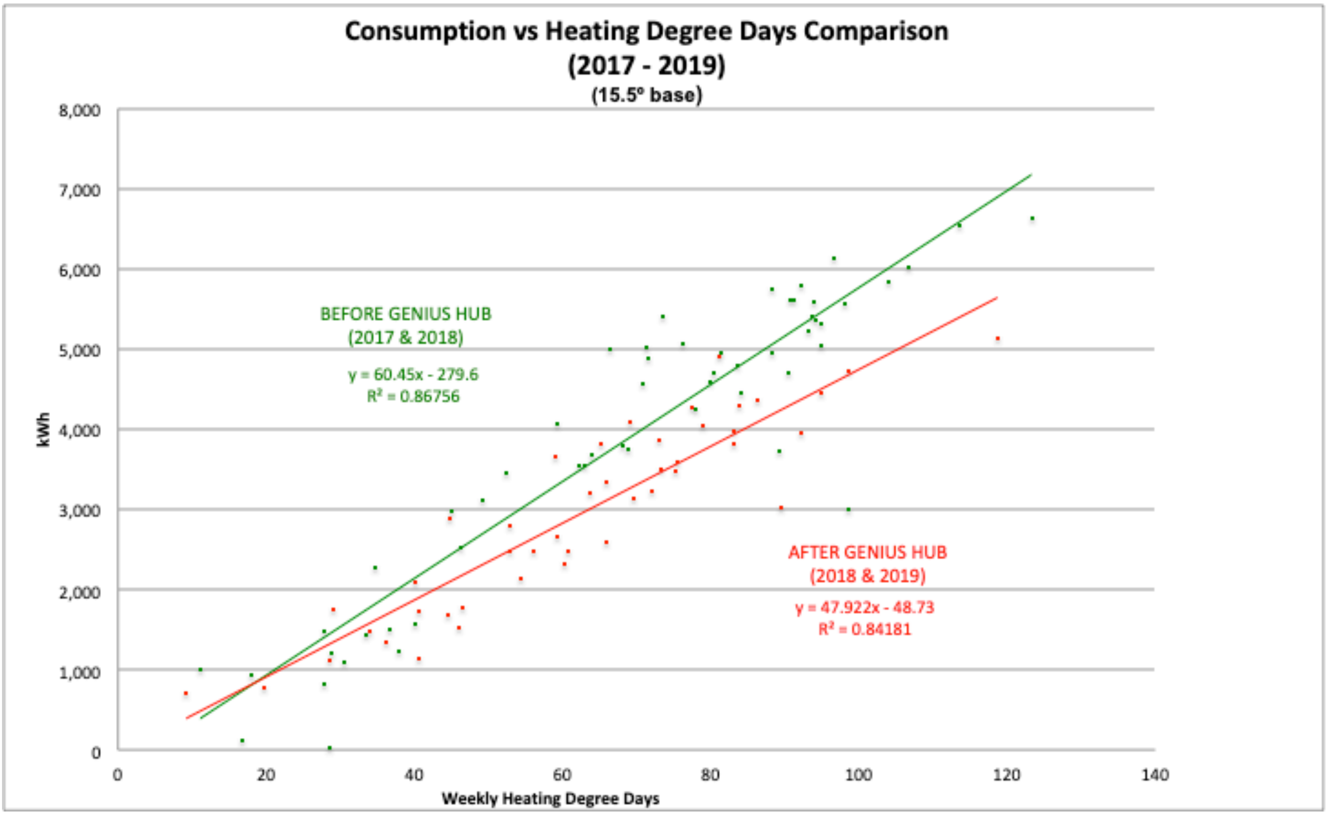


Figure 8 - *Graph comparing energy consumption per weekly heating degree days before and after installation of the Genius Hub (Figures 3 & 7 augmented).*

Figure 8 shows the energy usage as a function of weekly heating degree days pre and post-installation. As mentioned previously, data points (and thus lines of best fit) tend toward the bottom left corner of the plot and have a shallower gradient post installation compared with before the installation, this corresponds with greater efficiency. It is clear that the line drawn for 'AFTER GENIUS HUB' has lower energy usage per degree day, proving that the Genius Hub system has enhanced the efficiency of the heating controls within the building.

As part of this analysis it was noticed that despite the Genius Hub not calling the heating on at the weekends or during the night time gas is still being used at the weekend and at night. This is because the Genius Hub is not controlling the boilers, it is controlling the main circulation pumps. When there is no call for heat in the building the circulation pumps do not run, but the boilers and shunt pumps are running 24 hours a day and 7 days a week. It could be regarded that this is wasting energy and this energy usage during the night time and weekends has been calculated.

The average energy usage on Saturdays and Sundays for 2018 -> 2019 was 9% of the overall usage. In general the building is not used at the weekend so this represents the boiler running when it should not be keeping the low loss header hot when there is no demand for heat.

Assuming that the building is also not generally used between the times of 18:00 and 06:00 (50% of the day) this contributes to 12% of the overall usage keeping the low loss header hot when it was not required to be.

2.5 CONCLUSION & RECOMMENDATIONS

We have proven that, through robust statistical analysis, the Genius Hub system has saved Scottish Borders Council 21% off their energy over the course of 1 year since installation. The results have been presented to show a timeline of energy usage, both before & after installation, and to show the energy per weekly degree days, before & after installation.

If the boiler is also controlled as well as the main circulation pumps up to a further 12% could be saved during the night time and potentially 9% at the weekends (assuming that the building is not used during the night or at the weekends).

We have also shown a month-by-month breakdown of energy usage for concurrent months at the point of installation. This showed that for the majority of months, the Genius Hub system reduced the energy usage. For the months that increased the energy usage, users of the site have confirmed that this was because in the chambers the rooms were being overheated as a result of some issues with the size of the radiators in these rooms.

Qualification of Report

In accordance with the BREEAM education manual, an experienced energy specialist, using an approved energy modelling software tool, carried out the assessment. The energy specialist (Alasdair Woodbridge) has a master's degree in Mechanical Engineering specialising in Environmental Engineering, accreditation under the 'On Construction Domestic Energy Assessor and Code for Sustainable Homes Assessor' schemes, membership no. STRO006549, plus 8 years experience working on projects were carbon reduction has been a core part of the design.

The approved energy modelling software tool is FSAP2012, for which the energy specialist has accreditation as an energy assessor.

Supplementary information

Existing system infrastructure in the building

Boiler Control

The property is heated by two gas boilers (10 years and 2 years old), which are managed by timers.

Before the Genius Hub installation there were only two thermostats to shut the circulation pumps down when all of the rooms were up to temperature. The boilers are either on or off and heating the whole zone or not at all.

Boiler make and model serving main part of Building 1

Boilers serving main part of Building 1 and IT Suite

Boiler timer serving main part of Building 1

Domestic Boiler servicing Committee Rooms and IT Suite

Pumps - IT Suite

Pumps – Main part of Building 1

Room Control Before Installation

The heat is distributed through the building with modern 15mm copper pipework. The wet radiators had TRVs (Thermostatic Radiator Valves) to regulate the temperature in the rooms and appeared to be in good condition with exception of one (Entrance Hallway), which was broken.

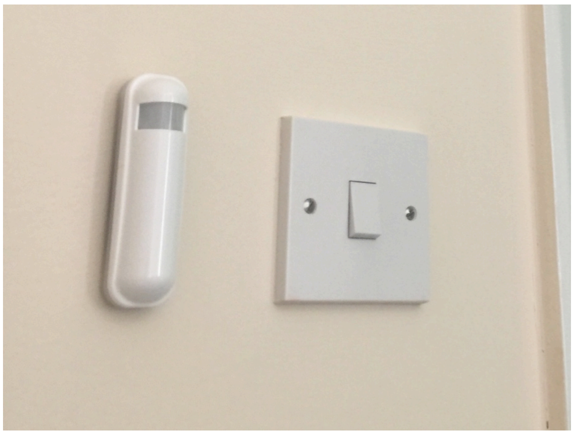
Convenor's Office – Newly updated TRV

Political Hallway - Standard Danfoss TRV

Committee Room 3 – Old Danfoss TRV

Entrance Hall (B1) – Broken Danfoss TRV

Room Control After Installation



Occupancy detectors (Genius Room Sensors) installed into each of the offices

Genius Radiator Valves, replaced existing TRVs

Range Extenders to boost the wireless signal around the building