Energy Consumption Analysis for

Village Hotels
The Belfry Hotel and Resort
(Jacklin House)

Saturday, 14 March 20

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1.0 Summary

1.1 ABSTRACT

The purpose of this report is to analyse the heat data provided by The Belfry Hotel for 'before' and 'after' the installation of the Genius Hub, which is used to control the temperature of the let rooms in the hotel. This is to determine the energy saved as a result of installing the Genius Hub system. This report considers 10 consecutive weeks' (2.5 months) heating energy data being supplied to 48 rooms in the Jacklin House block. This building is of modern construction with wet radiators in each room and frequently runs at high occupancy often above 95%.

This report found an average saving of 64% when comparing the original heating schedule with an occupancy based schedule over the trial period of 10 weeks. The trial consisted of alternating the heating schedule between 'Timer Mode' - where rooms are heated regardless of occupancy - and 'Sense Mode' - where only occupied rooms are heated. The mode of the heating was alternated for the first 4 weeks, spending 2 weeks in Timer Mode and 2 weeks in Sense Mode, and was then left in Sense Mode only for the next 6 weeks.

This test was carried out between 27th November 2019 – 5th February 2020. During the period of the trial it was reported that the number of complaints regarding the heating in Jacklin House reduced compared to before the Genius Hub was installed. A typical payback for a project such as this is between 2-5 years.

The Belfry Hotel were looking for a low cost and effective energy saving measure that could be easily retrofitted to the buildings across the resort with little or no disruption to the occupants of the building, and would not only reduce the cost of heating but also reduce complaints about the heating levels, as well as provide centralised control of the rooms for the maintenance team and reception.

1.2 PROJECT OUTLINE

Description of site

The Belfry Hotel and Resort is located in the West Midlands, 20 minutes from the centre of Birmingham and is set within 550 acres of beautiful North Warwickshire countryside. The hotel is an excellent example of a well maintained 4-star hotel, boasting 319 guest rooms, two restaurants, two bars, a nightclub, two spa pools, a sauna, solarium and an extensive gym. It also houses the UK headquarters of the PGA with three 18-hole golf courses and a driving range. Jacklin House was chosen for this pilot because it has consistently high occupancy levels and as such would be a rigorous test for the Genius Hub system but as a result would potentially show the lowest savings.

The guest rooms are spread over three floors and on each floor 16 rooms span a central corridor. They are of modern cavity wall construction with double glazing and the rooms had manual Thermostatic Radiator Valves (TRVs) before they were changed for wireless Genius Radiator Valves. No plumbing was required as part of the installation so each room took only 30 minutes (approx.) to change to 'smart' control. Each room has an en-suite bathroom which has no heating.

Heat is provided to the building with a heat exchanger in a plant room on the ground floor and the monitoring of the heat being supplied to the building during the trial was by a fiscal quality heat meter detailed later in this report.

A drawing of the ground floor of Jacklin House including details of the Genius Hub installation can be found in **figure 4**.

<u>Data capture</u>

Because the site only has a single gas meter for the whole site, it was not possible to analyse the savings in terms of gas consumption. To give robust data for analysis, a new heat energy meter was installed onto the heat exchanger for Jacklin House. A heat exchanger is equivalent to a boiler but takes the heat from a centralised heat plant as opposed to an individual local boiler. This provides heat to the radiators in the corridors and bedrooms exclusively and not the hot water for showers etc. Therefore it can be assumed that the data obtained from the heat meter accurately reflects the energy consumption of the space heating of the building.

Because no heat energy data was recorded before the Genius Hub was installed, it was agreed that 'bench mark' weeks would be run in conjunction with Genius Hub control. For a bench mark week, the heating schedule would be set to similar times to what it would have been before the Genius Hub system was installed. Using Timer Mode, the temperature was set to 23° during the daytime (when rooms are often left on) and 19° during the night time, **see figure 5**.

During the trial weeks the Genius Hub would also be run in Sense Mode where the rooms are programmed to hold a fixed temperature during the night of 17°, and during the middle of the day of 15°. If the room is occupied in the morning it would be heated to 20°C and in the evening it would be heated to 21°, see **figures 6 & 7**. Though 15° and 17° may appear to be too cold for 'comfort' the rooms are pre-heated up to 21° before guests get up in the morning and before they arrive in the afternoon/evening (regardless of occupancy) ensuring that the temperature is always comfortable prior to use.

The testing was carried out over ten consecutive weeks from 27/11/2019 to 05/02/2020 with a total of two weeks in Timer Mode and eight weeks in Sense Mode.

1.3 FUTURE PROJECTS

The purpose of running a pilot project was to assess whether the Genius Hub system meets the expectations of its ease of use and predicted energy savings. The success in these fields will lead to contracts for other buildings of The Belfry Hotel'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:

- 29/10/2019 – Genius Hub system installed into Jacklin House commissioned
- **27/11/19 – Week 1: Sense Mode**
    - Heat energy data analysis commences. All rooms running in Sense Mode
    - See **figure 6** for times and temperatures
- **06/12/19 – Week 2: Timer Mode**
    - All rooms running in Timer Mode
    - See **figure 5** for times and temperatures
- **13/12/19 – Week 3: Sense Mode (modified)**
    - All rooms running in Sense Mode
    - Sense Mode tweaked to come on earlier to make rooms warmer in the mornings
    - See **figure 7** for times and temperatures
- **21/12/19 – Week 4: Timer Mode**
    - All rooms running in Timer Mode
    - Same settings as 06/12/19
- **29/12/19 – Week 5-10: Sense Mode (modified)**
    - All rooms running in Sense Mode
    - Same settings as 13/12/19
- **05/02/20 - End of analysis**

2.0 Analysis

2.1 METHODOLOGY

Explanation of degree days

When calculating energy savings, day-to-day fluctuations of external temperature must be taken into account as this can have a significant impact on energy consumption. For example, during a warm winter less energy will be used to heat a property to, say, 20°C than it would during a cold winter. The unit of measurement 'kWh / Heating Degree Day °C' has been used for this report. 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. 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 on the data as much as possible.

The average internal temperature of a centrally heated home is 17.4°C (ONS Energy Consumption in the UK 2017 Update). Though there are no official regulations for hotel room temperature, it has been assumed that the internal temperature needs to be 19-20°C. For hotels or offices it is widely accepted that the internal heat gain is 3°C, meaning that when the external temperature drops below 16°C, heating is required to maintain comfort temperature. In this case, a Degree Day Base Temperature of 15.5° was chosen.

By normalising the energy use of the building 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 number of kWh used should be inversely proportional to the external temperature). However, in practice external factors disrupt this relationship.

Linear Regression Analysis has been carried out for the property using data from 27/11/2019 - 05/02/2020 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 it can be assumed that no heating is required to maintain an acceptable comfort level for the users of the building.

For both Timer Mode and Sense Mode a base temperature of 15.5° was established to be the best for this building.

2.2 THE RAW HEAT ENERGY DATA

Figure 1 below shows a heat map of the energy usage of the building. The columns are the hours of the day starting at midnight (00:00) on the left and finishing at the following midnight (24:00) on the right. Each row represents 1 day of the week. The colour of the cell indicates the amount of heat being used in that 30 minute period by the building. **GREEN** cells indicate no heating is being used, **ORANGE** cells indicate a nominal amount of heating is being used and **RED** cells indicate a lot of heat is being used by the building. The weeks alternate between Sense Mode and Timer Mode, with grey rows indicating days where the mode changes.

It is clear to see that during the night because a lower temperature was selected for the rooms there is no demand for heat by the Genius Hub. Starting in the morning at about 07:30 there is a period of high energy consumption as the rooms start heating before the guests get up. During the days where Sense Mode is running it is clear to see that the morning heating period uses less energy as rooms will be coming on at staggered times as guests rise at different times. Not all of the rooms will be occupied and in Sense Mode only the occupied rooms will heat. During the daytime (10:30 – 16:30), in Timer Mode it is clear that a substantial amount of energy is used throughout the day whereas in Sense Mode very little energy is used for heating.

An anomaly occurs on the 16/12 and 17/12 where heating was being used all day in the building and the system was in Sense Mode, suggesting that perhaps some maintenance work was being carried out on the system at that time or a room was continuously being boosted by a guest. After speaking with the hotel it was discovered that in the period of the first few weeks, if there was a comment about the heating by a guest then the maintenance team were instructed to remove the Genius valve and replace it with a standard TRV. This was done on the dates where unexpected heat usage was seen, but after two days the Genius Valves were replaced and the heat usage returns to what would be expected.

It is also clear to see where the rooms are being boosted more often during 19/01 - 21/01 and this corresponds to a cold snap where the average external temperature dropped as low as 1.4°C. During this time this confirms that the system manages itself well and when it's colder it will put more heat into the rooms where required, and guests are happy to boost the heat during the day if they think the room needs to be a little warmer.

Date	Day	Mode	Ave. Ext. Temp.	Total Energy (kWh)	Time of day (00:00 - 24:00)																																															
						1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21		22		23		24
27/11/2019	Wednesday	Sense	8.8	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	18	14	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	6	7	5	7	1	0	0	0	0	0	0
28/11/2019	Thursday	Sense	7.5	127	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	16	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	33	14	4	0	0	0	0	0	0	0	0
29/11/2019	Friday	Sense	2.5	178	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	17	16	18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	5	11	33	20	12	7	0	4	0	0	0	0	0	0
30/11/2019	Saturday	Sense	0.6	320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	23	19	25	2	0	0	0	0	0	0	0	0	4	4	13	11	13	25	16	26	17	21	18	15	7	5	14	5	0	0	0
01/12/2019	Sunday	Sense	2.1	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	44	18	18	24	3	0	0	0	0	0	0	0	0	0	0	0	12	18	14	25	30	22	13	12	18	17	2	2	5	2	0	0
02/12/2019	Monday	Sense	2.6	250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	36	25	23	21	9	4	0	0	0	0	0	0	0	0	0	0	7	5	25	14	27	18	16	13	6	0	0	0	0	0	0	0
03/12/2019	Tuesday	Sense	4.7	240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	41	24	23	19	1	0	0	0	0	0	0	0	0	0	0	0	0	0	21	15	27	19	17	17	12	3	0	0	0	0	0	0
04/12/2019	Wednesday	Sense	2.8	288	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47	23	24	22	3	0	0	0	0	0	0	0	0	0	0	0	0	0	30	20	24	29	29	21	14	2	0	0	0	0	0	0
05/12/2019	Thursday	Sense	6	286	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	20	27	29	3	1	1	1	0	0	0	0	0	0	0	0	0	0	28	17	29	40	26	18	0	0	0	0	0	0	0	0
06/12/2019	Friday	Sense/ Timer	10.1	704	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	73	51	43	39	37	40	42	37	30	34	30	26	28	27	22	14	18	22	18	18	14	8	0	0	0	0	0	0	0	0	0	0
07/12/2019	Saturday	Timer	8.9	467	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	16	47	22	23	23	24	23	18	20	24	21	20	18	17	16	21	16	11	7	11	8	1	8	9	11	1	0	0	0	0	0	0	0
08/12/2019	Sunday	Timer	8.1	489	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	13	43	15	15	18	20	20	19	20	26	21	24	23	24	20	22	24	19	18	16	9	11	7	0	10	2	1	0	0	0	0	0	0
09/12/2019	Monday	Timer	6.1	526	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	18	44	27	19	22	15	18	18	24	20	22	25	25	23	21	20	23	20	18	17	16	13	1	8	15	1	0	0	0	0	0	0	0
10/12/2019	Tuesday	Timer	7.2	626	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	24	51	24	25	30	31	31	31	34	30	25	26	26	22	22	22	20	18	19	19	17	17	15	10	4	0	0	0	0	0	0	0	0
11/12/2019	Wednesday	Timer	3.6	657	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	19	47	26	24	32	30	32	31	30	29	27	26	29	21	25	22	24	23	21	19	19	22	17	15	15	2	0	0	0	0	0	0	0
12/12/2019	Thursday	Timer	4.7	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	21	48	29	28	33	36	34	31	29	21	23	23	22	21	21	18	15	13	14	6	2	0	0	1	0	0	0	0	0	0	0	0	0
13/12/2019	Friday	Timer/ Sense	6.1	552	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	17	42	20	21	26	24	26	26	27	27	25	21	22	20	23	18	17	18	17	15	15	20	14	14	5	0	0	0	0	0	0	0	0
14/12/2019	Saturday	Sense	4.7	108	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	23	12	0	17	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	29	14	8	0	1	0	0	0	0	0	0
15/12/2019	Sunday	Sense	4.8	251	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	28	16	14	2	0	0	0	0	0	0	0	0	0	0	0	15	18	14	14	13	17	10	11	15	18	15	11	15	0	1	0	0
16/12/2019	Monday	Sense	4.1	293	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	32	17	14	17	13	13	5	6	7	6	11	7	9	6	13	7	1	3	9	11	16	9	10	12	15	15	4	4	0	0	0	0
17/12/2019	Tuesday	Sense	2.5	323	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	32	12	16	16	5	7	9	8	11	10	9	9	8	9	5	5	11	12	18	13	21	16	16	13	8	6	10	7	0	0	0	0
18/12/2019	Wednesday	Sense	5.4	214	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	32	23	19	20	4	0	0	0	0	0	0	0	0	0	0	1	0	0	14	10	20	13	15	18	4	1	8	10	0	0	0	0
19/12/2019	Thursday	Sense	10.1	152	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	28	12	11	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	1	12	19	19	12	11	3	2	0	0	0	0	0
20/12/2019	Friday	Sense	6.3	162	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	5	8	6	0	0	0	0	0	0	0	0	0	0	0	0	5	6	15	12	12	15	16	16	16	6	0	0	0	1	0	0
21/12/2019	Saturday	Sense/ Timer	6.1	395	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	18	16	9	2	0	0	0	0	3	1	0	1	2	1	6	62	49	41	38	33	29	27	25	2	0	0	0	0	0	0	0
22/12/2019	Sunday	Timer	6.7	643	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	18	50	29	29	23	23	27	28	27	30	30	29	26	23	24	27	29	20	21	18	19	14	15	15	17	3	0	0	0	0	0	0	0
23/12/2019	Monday	Timer	6.9	551	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	19	52	26	25	25	16	23	25	28	26	26	21	25	21	19	17	20	17	17	11	6	18	14	13	12	0	0	0	0	0	0	0	0
24/12/2019	Tuesday	Timer	7.8	469	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	21	51	30	21	22	20	24	25	18	16	18	15	19	18	16	12	2	13	16	18	15	15	10	2	2	0	0	0	0	0	0	0	0
25/12/2019	Wednesday	Timer	4.3	489	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	15	42	19	15	17	22	25	21	19	17	18	21	16	17	15	15	17	18	15	16	14	13	17	16	18	1	0	0	2	0	0	0	0
26/12/2019	Thursday	Timer	4.5	523	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	16	46	21	17	23	20	27	21	24	22	21	19	18	17	19	18	16	17	16	23	18	14	14	14	13	1	0	0	0	0	0	0	0
27/12/2019	Friday	Timer	5.2	476	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	22	42	25	20	21	22	27	27	23	23	23	20	22	22	18	15	18	15	14	8	0	12	5	4	0	0	0	0	0	0	0	0	0
28/12/2019	Saturday	Timer	7.9	407	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	12	40	18	15	18	21	21	19	18	16	19	19	16	18	16	13	15	16	6	4	8	15	12	10	0	0	0	0	0	0	0	0	0
29/12/2019	Sunday	Timer/ Sense	7	434	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	13	39	15	10	6	15	16	20	18	21	19	19	18	19	16	19	17	7	0	7	12	9	19	14	13	7	6	2	8	6	2	0	0
30/12/2019	Monday	Sense	5.4	82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	11	16	12	0	5	10	3	0	0	0	0	0
31/12/2019	Tuesday	Sense	6.8	144	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	9	12	6	0	1	0	1	0	0	0	0	0	0	0	0	15	15	8	5	14	9	9	5	4	6	1	1	0	0	0	0
01/01/2020	Wednesday	Sense	5.8	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	1	8	6	7	7	4	0	0	0	0	0	5	2	0	9	0	0	6	5	0	0	0	0	0	0	0
02/01/2020	Thursday	Sense	8.5	94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	1	23	21	19	6	0	0	0	0	0	0	0	0
03/01/2020	Friday	Sense	7.2	122	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	19	24	16	14	13	11	1	1	5	0	0	0	0
04/01/2020	Saturday	Sense	7.1	81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	14	17	4	2	8	0	2	1	0	0	0	0	0
05/01/2020	Sunday	Sense	7.3	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	7	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	17	18	16	3	8	2	0	1	0	0	0	0	3	0
06/01/2020	Monday	Sense	7.1	155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	7	14	14	3	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	12	24	16	20	13	4	0	0	0	0	0	0
07/01/2020	Tuesday	Sense	9.4	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	15	8	4	1	4	0	1	0	0	0	0	0	4	0	0	8	7	7	0	30	25	19	6	0	0	0	0	0	0	0	0
08/01/2020	Wednesday	Sense	9.5	110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	12	21	20	5	0	0	1	0	0	0	0
09/01/2020	Thursday	Sense	8.4	81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	21	7	7	11	10	3	0	0	0	0	0	0
10/01/2020	Friday	Sense	5.5	262	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	10	17	2	0	0	0	0	0	0	0	0	0	12	10	7	5	18	15	19	20	27	22	16	13	6	13	0	0	0	0
11/01/2020	Saturday	Sense	9.1	229	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	34	9	17	16	1	0	9	10	0	0	0	0	0	0	4	0	16	12	16	11	20	17	12	7	14	1	0	0	0	0	0	0
12/01/2020	Sunday	Sense	7.8	119	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	8	6	0	6	0	0	0	0	0	0	0	3	6	0	0	0	13	16	14	11	8	9	3	0	0	0	0	0	0
13/01/2020	Monday	Sense	6	186	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	12	3	0	0	4	13	6	5	3	6	2	2	0	0	1	0	0	13	0	16	25	16	16	11	0	2	8	0	0	0	0
14/01/2020	Tuesday	Sense	8.5	151	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	18	9	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	37	26	18	2	0	0	0	0	0	0	0
15/01/2020	Wednesday	Sense	6.5	218	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	9	15	17	8	0	0	0	0	0	0	0	0	0	0	0	0	4	17	15	16	29	18	16	17	11	2	0	0	0	0	0
16/01/2020	Thursday	Sense	7.8	185	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	39	18	14	17	1	0	0	0	0	0	0	0	0	0	0	0	0	0	12	19	25	16	15	8	0	0	0	0	0	0	0	0
17/01/2020	Friday	Sense	5.4	192	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	7	3	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	12	30	23	23	16	16	6	0	0	0	0	0	0
18/01/2020	Saturday	Sense	4	235	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	36	14	9	10	0	2	0	0	0	0	0	0	3	0	0	0	0	0	16	21	26	23	19	15	21	13	3	0	0	0	0	0
19/01/2020	Sunday	Sense	1.4	335	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	15	12	12	6	3	5	0	3	9	7	1	0	9	11	3	9	11	18	20	17	19	16	17	19	16	14	14	0	3	10	5
20/01/2020	Monday	Sense	2.8	414	4	3	0	0	0	0	0	0	0	0	0	0	1	5	0	8	34	18	18	18	11	10	17	13	14	11	11	10	9	14	9	10	9	12	13	12	21	16	22	13	6	11	9	14	7	0	1	0
21/01/2020	Tuesday	Sense	4.3	292	0	0	0	0	0	0	0	0	0	0	0	0	3	10	2	1	35	21	17	20	6	2	6	6	7	1	1	0	0	0	8	0	0	0	11	17	31	27	17	15	15	8	5	0	0	0	0	0
22/01/2020	Wednesday	Sense	8	111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	34	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	18	9	13	7	0	0	0	0	0	0
23/01/2020	Thursday	Sense	6.6	119	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	22	11	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	11	15	11	4	10	21	7	0	0	0	0	0	0	0	0
24/01/2020	Friday	Sense	6.2	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	4	4	1	0	0	0	0	0	0	0	0	0	1	11	9	0	6	2	5	25	24	13	4	0	0	0	0	0	0	0	0
25/01/2020	Saturday	Sense	5.5	177	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	12	0	0	0	0	0	0	0	0	2	0	0	0	14	12	7	7	11	2	31	19	13	13	1	0	0	0	0	0	0	0
26/01/2020	Sunday	Sense	7.1	140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	12	12	9	2	24	20	15	14	1	2	1	0	0	0	0	0
27/01/2020	Monday	Sense	5.5	130	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	25	4	3	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	14	10	22	14	12	12	1	0	0	0	0	0
28/01/2020	Tuesday	Sense	3.8	220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	20	19	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	20	4	9	7	43	25	13	5	0	0	0	0	1	5
29/01/2020	Wednesday	Sense	5.9	295	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	27	17	13	2	0	0	0	0	0	2	10	6	6	7	3	0	0	20	13	19	26	23	18	14	6	0	0	0	6	5	0
30/01/2020	Thursday	Sense	8.7	200	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	19	20	10	2	0	0	0	0	0	0	0	3	10	2	0	0	0	0	5	41	23	12	10	1	0	0	0	0	0	0	0
31/01/2020	Friday	Sense	9.8	157	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	4	11	11	1	0	0	0	0	0	0	0	0	0	0	1	6	10	10	16	25	11	14	4	7	0	0	0	0	0	0	0
01/02/2020	Saturday	Sense	9	113	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	3	1	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	16	14	13	14	0	0	0	0	0	0	0
02/02/2020	Sunday	Sense	8.6	128	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	25	7	2	4	2	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	18	15	14	14	6	0	0	0	0	0	2	7
03/02/2020	Monday	Sense	7.7	128	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	14	7	7	6	9	7	0	0	0	0	0	0	0	0	0	0	0	0	0	32	19	4	0	0	0	0	0	0	0	0	0
04/02/2020	Tuesday	Sense	6.5	143	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	17	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	16	16	14	14	0	0	0	0	0	0	0
05/02/2020	Wednesday	Sense	5.7	151	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	17	14	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	12	27	15	13	6	0	3	3	0	0	0	0	0

Figure 1 *- Heat Map of the energy use of the building. A larger version of this can be found in* ***figure 8****.*

2.3 NORMALISING ENERGY USAGE USING DEGREE DAYS

Normalising the heating energy data against the external temperature takes into account the fact that on colder days more energy is required to heat the building compared with a warmer day. This means that any two given days, weeks or months' energy consumption can be considered as having equal bearing when comparing the energy usage of a building.

Figure 2 below plots the normalised energy consumption of the building (i.e. energy consumption divided by the external temperature), against the date. It is clear to see that when the building is running in Timer Mode, the building has a higher heat demand (kWh) than in the subsequent weeks where the building is in Sense Mode. For clarity, the average daily temperature is plotted on the same chart in red and shows that during the ten weeks of analysis the external air temperature did not fluctuate significantly. This also indicates that the building required heating as the external temperature held between a range of 0 – 10°C.

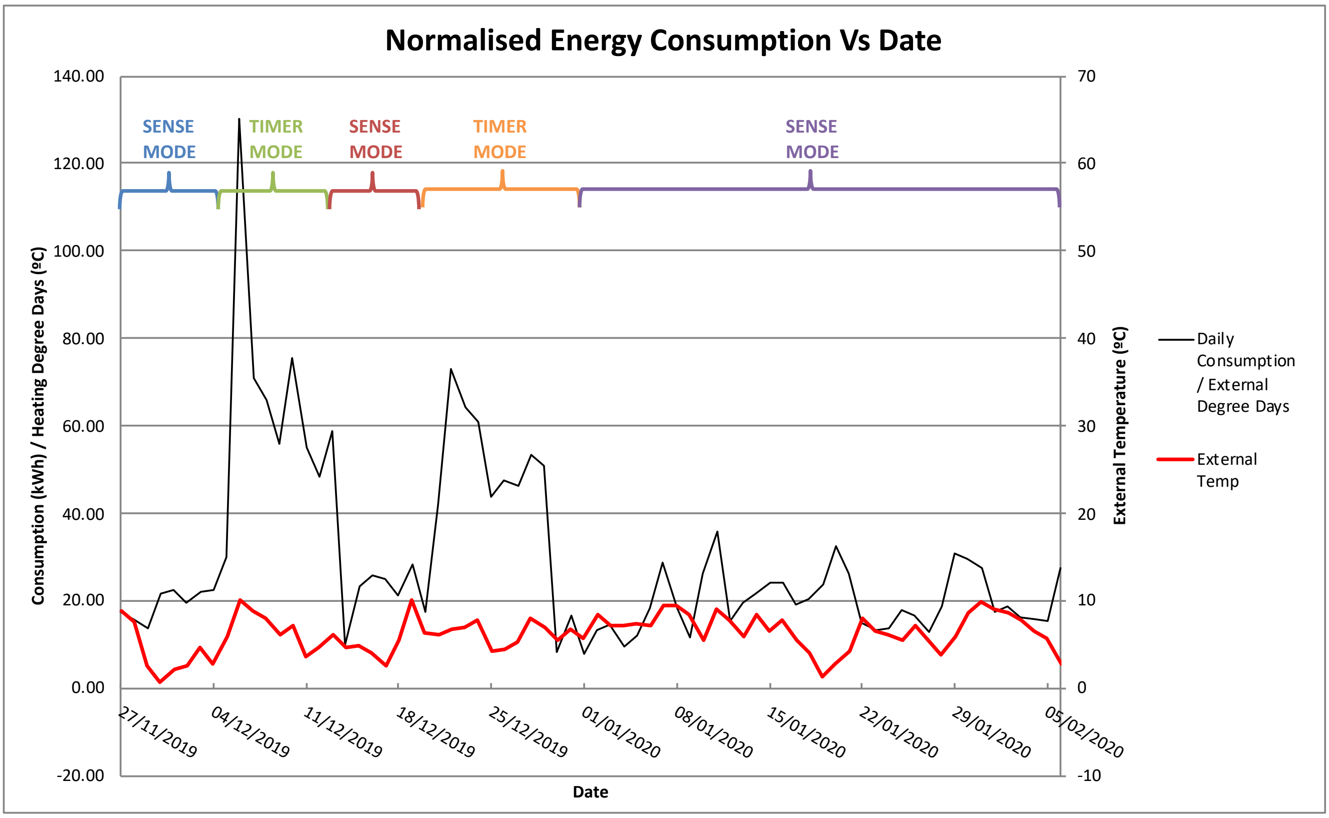

***Figure 2** - Chart showing the normalised energy consumption (the energy consumption divided by the heating degree days) plotted against the date. The external temperature is also shown.*

2.4 COMPARING ENERGY CONSUMPTION AGAINST DEGREE DAYS

Another way of comparing the energy usage, taking into account the influence of the external temperature, is to plot the energy consumption against the heating degree days, see **figure 3** below. Each data point on the chart below represents one day. The x-axis plots heating degree days for a given day. Data points with low degree day values represent warmer days and should in theory require less energy be used on heating. The y-axis plots the amount of energy consumed by the building that day.

Data points in the top right region of the chart show that the day was cold (a high degree day) and the energy consumption for heating was high. Data points in the bottom left region of the chart show that the day was warm (a low degree day) and the energy consumption for heating was low.

The data has been grouped the data by week and drawn lines of best fit for each week. Weeks 1 (blue), 3 (red) & 5 - 10 (purple) show less energy consumption for approximately the same range of degree days as weeks 2 (green) & 4 (orange). Weeks 2 and 4 required significantly more heating for approximately the same range of degree days.

It is possible to draw a line of best fit of the form $y = mx + c$ for each data set and the equation of this line can give the energy usage for any particular day. Each week's line of best fit and its equation are shown in **figure 3**. The general formula is given below.

$$y = mx + c$$

Energy Consumption (kWh) = Normalised Energy Consumption (kWh / degree days) * degree days + intercept

The average temperature over the ten weeks of analysis was 6.2°C. With a base temperature of 15.5°C this equals an average of **9.3 degree days** (15.5 – 6.2 = 9.3).

Using **9.3 degree days** as **x** in the above equation, the average energy usage can be calculated for each week of analysis.

- Week 1 – Sense Mode
  - y = 20.629x + 0.5397
  - (20.629 x 9.3) + 0.5397 = **191 kWh**
- Week 2 – Timer Mode
  - y = 23.941x + 330.6
  - (23.941 x 9.3) + 330.6 = **552 kWh**
- Week 3 – Sense Mode
  - y = 20.830x + 4.627
  - (20.830 x 9.3) + 4.627 = **197 kWh**
- Week 4 – Timer Mode
  - y = 6.8576x + 444.41
  - (6.8576 x 9.3) + 444.41 = **508 kWh**
- Week 5 - 13 – Sense Mode
  - y = 23.862x – 41.1431
  - (23.862 x 9.3) – 41.1431 = **179 kWh**

Average Energy usage in Sense Mode = 191 + 197 + 179 = **189 kWh**

Average Energy usage in Timer Mode = 552 + 508 = **530 kWh**

Total savings = (530 – 189) / 530 = **64%**

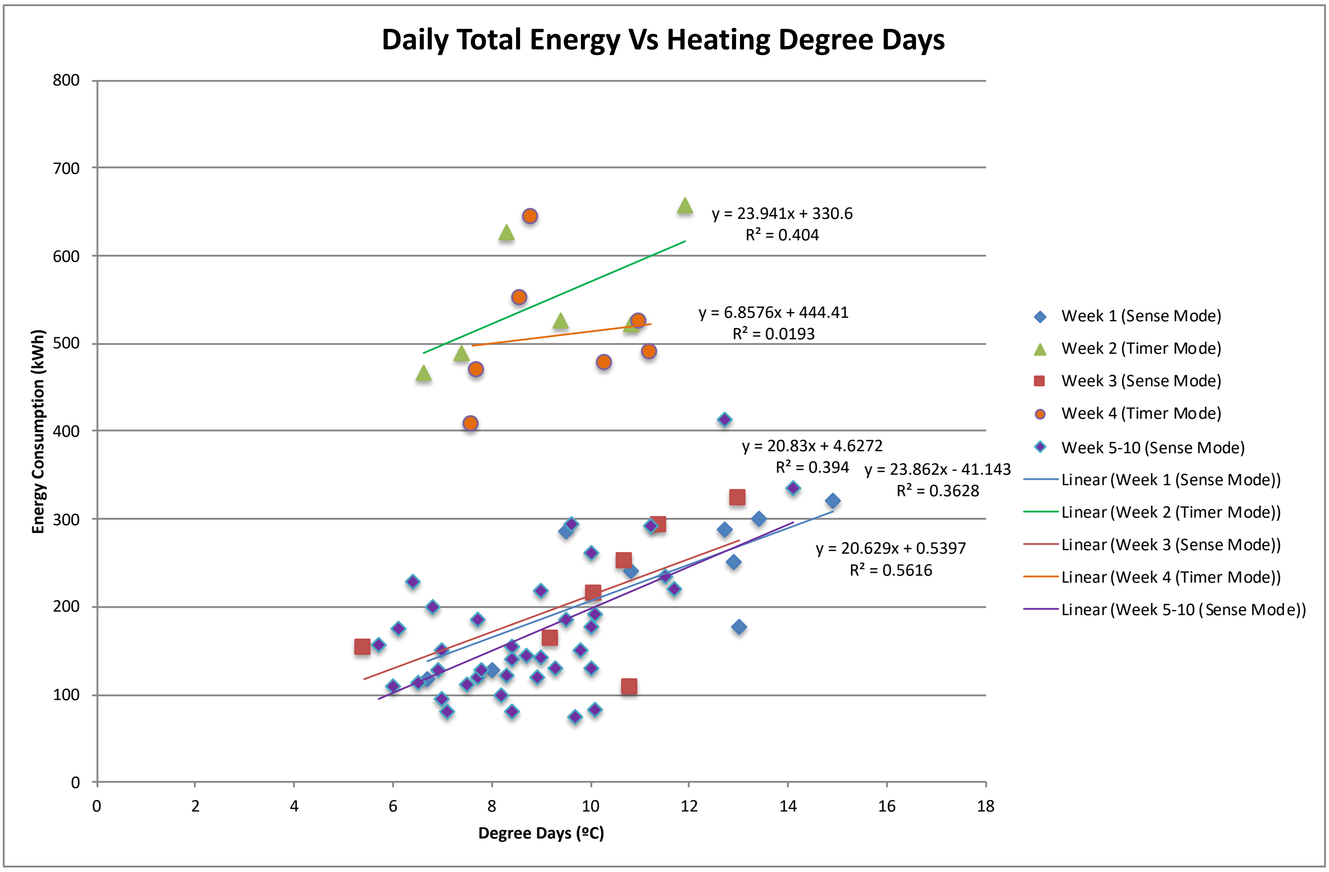

***Figure 3** - Chart showing the energy consumption of the building plotted against the heating degree days, split into 5 groups of data for the weeks spent in Timer Mode or Sense Mode*

2.5 CONCLUSION & RECOMMENDATIONS

It has been proven that, through robust statistical analysis of 10 weeks' data, the Genius Hub system has saved The Belfry Hotel 64% from their energy costs for heating Jacklin House. The results have been presented to show a timeline of energy usage, both in Timer Mode and in Sense Mode to simulate before and after installation.

It is recommended that if another M&V report is to be produced for other parts of the site monitoring equipment should be installed and data captured during the heating months a minimum of 1 month before the Genius Hub system is installed so that data from both before and after installation can be compared. This would also negate the need for the Genius Hub system to heat the whole building after installation, as was required for this report.

3.0 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 10 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.

4.0 Supplementary Information

Figure 4 - *Example of ground floor installation of Genius Hub*

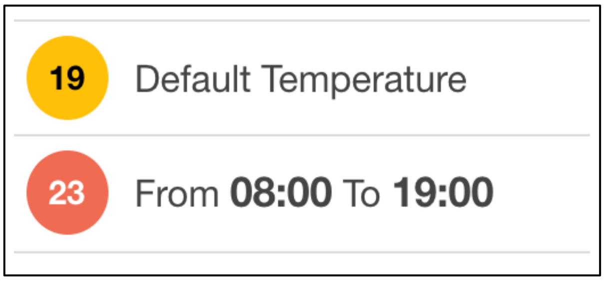

Figure 5 - *Example of Timer Mode schedule for dates:*
07/12/19 –> 12/12/19 &
22/12/19 –> 28/12/19

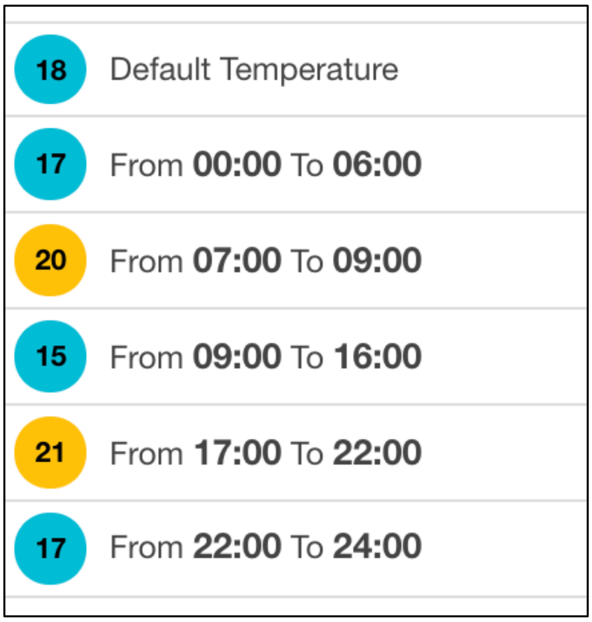

Figure 6 *- Example of Sense Mode schedule for dates:*
27/11/19 –> 05/12/19

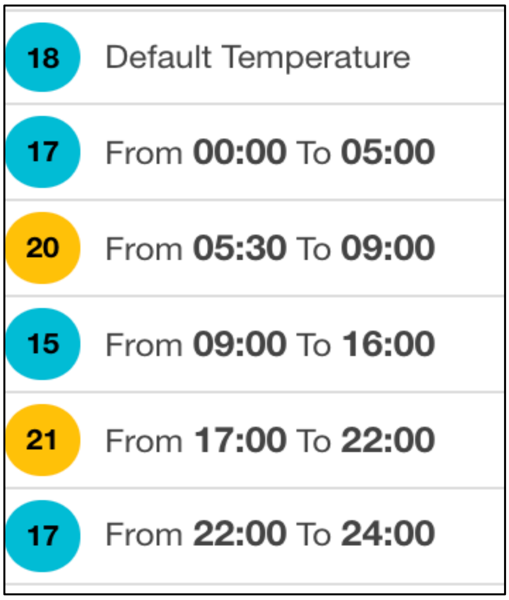

Figure 7 *- Example of Sense Mode schedule for dates:*
14/12/19 –> 20/12/19
30/12/19 –> 05/01/20

Date	Day	Mode	Ave. Ext. Temp.	Total Energy (kWh)	Time of day (00:00 - 24:00)																																													
						1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21		22		23		24
27/11/2019	Wednesday	Sense	8.8	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	18	14	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	6	7	5	7	1	0	0	0	0	0	0
28/11/2019	Thursday	Sense	7.5	127	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	16	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	33	14	4	0	0	0	0	0	0	0	0
29/11/2019	Friday	Sense	2.5	178	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	17	16	18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	5	11	33	20	12	7	0	4	0	0	0	0	0	0
30/11/2019	Saturday	Sense	0.6	320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	23	19	25	2	0	0	0	0	0	0	0	0	4	4	13	11	13	25	16	26	17	21	18	15	7	5	14	5	0	0	0
01/12/2019	Sunday	Sense	2.1	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	44	18	18	24	3	0	0	0	0	0	0	0	0	0	0	0	12	18	14	25	30	22	13	12	18	17	2	2	5	2	0	0
02/12/2019	Monday	Sense	2.6	250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	36	25	23	21	9	4	0	0	0	0	0	0	0	0	0	0	7	5	25	14	27	18	16	13	6	0	0	0	0	0	0	0
03/12/2019	Tuesday	Sense	4.7	240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	41	24	23	19	1	0	0	0	0	0	0	0	0	0	0	0	0	0	21	15	27	19	17	17	12	3	0	0	0	0	0	0
04/12/2019	Wednesday	Sense	2.8	288	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47	23	24	22	3	0	0	0	0	0	0	0	0	0	0	0	0	0	30	20	24	29	29	21	14	2	0	0	0	0	0	0
05/12/2019	Thursday	Sense	6	286	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	20	27	29	3	1	1	1	0	0	0	0	0	0	0	0	0	0	28	17	29	40	26	18	0	0	0	0	0	0	0	0
06/12/2019	Friday	Sense/ Timer	10.1	704	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	73	51	43	39	37	40	42	37	30	34	30	26	28	27	22	14	18	22	18	18	14	8	0	0	0	0	0	0	0	0	0	0
07/12/2019	Saturday	Timer	8.9	467	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	16	47	22	23	23	24	23	18	20	24	21	20	18	17	16	21	16	11	7	11	8	1	8	9	11	1	0	0	0	0	0	0	0
08/12/2019	Sunday	Timer	8.1	489	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	13	43	15	15	18	20	20	19	20	26	21	24	23	24	20	22	24	19	18	16	9	11	7	0	10	2	1	0	0	0	0	0	0
09/12/2019	Monday	Timer	6.1	526	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	18	44	27	19	22	15	18	18	24	20	22	25	25	23	21	20	23	20	18	17	16	13	1	8	15	1	0	0	0	0	0	0	0
10/12/2019	Tuesday	Timer	7.2	626	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	24	51	24	25	30	31	31	31	34	30	25	26	26	22	22	22	20	18	19	19	17	17	15	10	4	0	0	0	0	0	0	0	0
11/12/2019	Wednesday	Timer	3.6	657	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	19	47	26	24	32	30	32	31	30	29	27	26	29	21	25	22	24	23	21	19	19	22	17	15	15	2	0	0	0	0	0	0	0
12/12/2019	Thursday	Timer	4.7	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	21	48	29	28	33	36	34	31	29	21	23	23	22	21	21	18	15	13	14	6	2	0	0	1	0	0	0	0	0	0	0	0	0
13/12/2019	Friday	Timer/ Sense	6.1	552	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	17	42	20	21	26	24	26	26	27	27	25	21	22	20	23	18	17	18	17	15	15	20	14	14	5	0	0	0	0	0	0	0	0
14/12/2019	Saturday	Sense	4.7	108	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	23	12	0	17	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	29	14	8	0	1	0	0	0	0	0	0	0
15/12/2019	Sunday	Sense	4.8	251	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	28	16	14	2	0	0	0	0	0	0	0	0	0	0	0	15	18	14	14	13	17	10	11	15	18	15	11	15	0	1	0	0
16/12/2019	Monday	Sense	4.1	293	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	32	17	14	17	13	13	5	6	7	6	11	7	9	6	13	7	1	3	9	11	16	9	10	12	15	15	4	4	0	0	0	0
17/12/2019	Tuesday	Sense	2.5	323	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	32	12	16	16	5	7	9	8	11	10	9	9	8	9	5	5	11	12	18	13	21	16	16	13	8	6	10	7	0	0	0	0
18/12/2019	Wednesday	Sense	5.4	214	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	32	23	19	20	4	0	0	0	0	0	0	0	0	0	0	1	0	0	14	10	20	13	15	18	4	1	8	10	0	0	0	0
19/12/2019	Thursday	Sense	10.1	152	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	28	12	11	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	1	12	19	19	12	11	3	2	0	0	0	0	0
20/12/2019	Friday	Sense	6.3	162	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	5	8	6	0	0	0	0	0	0	0	0	0	0	0	0	5	6	15	12	12	15	16	16	16	6	0	0	0	1	0	0
21/12/2019	Saturday	Sense/ Timer	6.1	395	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	18	16	9	2	0	0	0	0	3	1	0	1	2	1	6	62	49	41	38	33	29	27	25	2	0	0	0	0	0	0	0
22/12/2019	Sunday	Timer	6.7	643	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	18	50	29	29	23	23	27	28	27	30	30	29	26	23	24	27	29	20	21	18	19	14	15	15	17	3	0	0	0	0	0	0	0
23/12/2019	Monday	Timer	6.9	551	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	19	52	26	25	25	16	23	25	28	26	26	21	25	21	19	17	20	17	17	11	6	18	14	13	12	0	0	0	0	0	0	0	0
24/12/2019	Tuesday	Timer	7.8	469	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	21	51	30	21	22	20	24	25	18	16	18	15	19	18	16	12	2	13	16	18	15	15	10	2	2	0	0	0	0	0	0	0	0
25/12/2019	Wednesday	Timer	4.3	489	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	15	42	19	15	17	22	25	21	19	17	18	21	16	17	15	15	17	18	15	16	14	13	17	16	18	1	0	0	2	0	0	0	0
26/12/2019	Thursday	Timer	4.5	523	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	16	46	21	17	23	20	27	21	24	22	21	19	18	17	19	18	16	17	16	23	18	14	14	14	13	1	0	0	0	0	0	0	0
27/12/2019	Friday	Timer	5.2	476	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	22	42	25	20	21	22	27	27	23	23	23	20	22	22	18	15	18	15	14	8	0	12	5	4	0	0	0	0	0	0	0	0	0
28/12/2019	Saturday	Timer	7.9	407	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	12	40	18	15	18	21	21	19	18	16	19	19	16	18	16	13	15	16	6	4	8	15	12	10	0	0	0	0	0	0	0	0	0
29/12/2019	Sunday	Timer/ Sense	7	434	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	13	39	15	10	6	15	16	20	18	21	19	19	18	19	16	19	17	7	0	7	12	9	19	14	13	7	6	2	8	6	2	0	0

Figure 8.1 *- Heat Map showing the hours of the day heating is required*

Date	Day	Mode	Ave. Ext. Temp.	Total Energy (kWh)	Time of day (00:00 - 24:00)																																														
						1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21		22		23		24
30/12/2019	Monday	Sense	5.4	82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	11	16	12	0	5	10	3	0	0	0	0	0
31/12/2019	Tuesday	Sense	6.8	144	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	9	12	6	0	1	0	1	0	0	0	0	0	0	0	0	15	15	8	5	14	9	9	5	4	6	1	1	0	0	0	0
01/01/2020	Wednesday	Sense	5.8	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	1	8	6	7	7	4	0	0	0	0	0	5	2	0	9	0	0	6	5	0	0	0	0	0	0	0
02/01/2020	Thursday	Sense	8.5	94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	1	23	21	19	6	0	0	0	0	0	0	0	0
03/01/2020	Friday	Sense	7.2	122	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	19	24	16	14	13	11	1	1	5	0	0	0	0
04/01/2020	Saturday	Sense	7.1	81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	14	17	4	2	8	0	2	1	0	0	0	0	0
05/01/2020	Sunday	Sense	7.3	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	7	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	17	18	16	3	8	2	0	1	0	0	0	0	3	0
06/01/2020	Monday	Sense	7.1	155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	7	14	14	3	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	12	24	16	20	13	4	0	0	0	0	0	0
07/01/2020	Tuesday	Sense	9.4	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	15	8	4	1	4	0	1	0	0	0	0	0	4	0	0	8	7	7	0	30	25	19	6	0	0	0	0	0	0	0	0
08/01/2020	Wednesday	Sense	9.5	110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	12	21	20	5	0	0	1	0	0	0	0
09/01/2020	Thursday	Sense	8.4	81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	21	7	7	11	10	3	0	0	0	0	0	0
10/01/2020	Friday	Sense	5.5	262	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	10	17	2	0	0	0	0	0	0	0	0	0	12	10	7	5	18	15	19	20	27	22	16	13	6	13	0	0	0	0
11/01/2020	Saturday	Sense	9.1	229	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	34	9	17	16	1	0	9	10	0	0	0	0	0	0	4	0	16	12	16	11	20	17	12	7	14	1	0	0	0	0	0	0
12/01/2020	Sunday	Sense	7.8	119	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	8	6	0	6	0	0	0	0	0	0	0	3	6	0	0	0	13	16	14	11	8	9	3	0	0	0	0	0	0
13/01/2020	Monday	Sense	6	186	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	12	3	0	0	4	13	6	5	3	6	2	2	0	0	1	0	0	13	0	16	25	16	16	11	0	2	8	0	0	0	0
14/01/2020	Tuesday	Sense	8.5	151	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	18	9	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	37	26	18	2	0	0	0	0	0	0	0
15/01/2020	Wednesday	Sense	6.5	218	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	9	15	17	8	0	0	0	0	0	0	0	0	0	0	0	0	4	17	15	16	29	18	16	17	11	2	0	0	0	0	0
16/01/2020	Thursday	Sense	7.8	185	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	39	18	14	17	1	0	0	0	0	0	0	0	0	0	0	0	0	0	12	19	25	16	15	8	0	0	0	0	0	0	0	0
17/01/2020	Friday	Sense	5.4	192	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	7	3	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	12	30	23	23	16	16	6	0	0	0	0	0	0
18/01/2020	Saturday	Sense	4	235	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	36	14	9	10	0	2	0	0	0	0	0	0	3	0	0	0	0	0	16	21	26	23	19	15	21	13	3	0	0	0	0	0
19/01/2020	Sunday	Sense	1.4	335	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	15	12	12	6	3	5	0	3	9	7	1	0	9	11	3	9	11	18	20	17	19	16	17	19	16	14	14	0	3	10	5
20/01/2020	Monday	Sense	2.8	414	4	3	0	0	0	0	0	0	0	0	0	0	1	5	0	8	34	18	18	18	11	10	17	13	14	11	11	10	9	14	9	10	9	12	13	12	21	16	22	13	6	11	9	14	7	0	1	0
21/01/2020	Tuesday	Sense	4.3	292	0	0	0	0	0	0	0	0	0	0	0	0	3	10	2	1	35	21	17	20	6	2	6	6	7	1	1	0	0	0	8	0	0	0	11	17	31	27	17	15	15	8	5	0	0	0	0	0
22/01/2020	Wednesday	Sense	8	111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	34	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	18	9	13	7	0	0	0	0	0	0
23/01/2020	Thursday	Sense	6.6	119	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	22	11	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	11	15	11	4	10	21	7	0	0	0	0	0	0	0	0
24/01/2020	Friday	Sense	6.2	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	4	4	1	0	0	0	0	0	0	0	0	0	1	11	9	0	6	2	5	25	24	13	4	0	0	0	0	0	0	0	0
25/01/2020	Saturday	Sense	5.5	177	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	12	0	0	0	0	0	0	0	0	2	0	0	0	14	12	7	7	11	2	31	19	13	13	1	0	0	0	0	0	0	0
26/01/2020	Sunday	Sense	7.1	140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	12	12	9	2	24	20	15	14	1	2	1	0	0	0	0	0
27/01/2020	Monday	Sense	5.5	130	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	25	4	3	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	14	10	22	14	12	12	1	0	0	0	0	0
28/01/2020	Tuesday	Sense	3.8	220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	20	19	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	20	4	9	7	43	25	13	5	0	0	0	0	1	5
29/01/2020	Wednesday	Sense	5.9	295	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	27	17	13	2	0	0	0	0	0	2	10	6	6	7	3	0	0	20	13	19	26	23	18	14	6	0	0	0	6	5	0
30/01/2020	Thursday	Sense	8.7	200	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	19	20	10	2	0	0	0	0	0	0	0	3	10	2	0	0	0	0	5	41	23	12	10	1	0	0	0	0	0	0	0
31/01/2020	Friday	Sense	9.8	157	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	4	11	11	1	0	0	0	0	0	0	0	0	0	0	1	6	10	10	16	25	11	14	4	7	0	0	0	0	0	0	0
01/02/2020	Saturday	Sense	9	113	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	3	1	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	16	14	13	14	0	0	0	0	0	0	0
02/02/2020	Sunday	Sense	8.6	128	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	25	7	2	4	2	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	18	15	14	14	6	0	0	0	0	0	2	7
03/02/2020	Monday	Sense	7.7	128	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	14	7	7	6	9	7	0	0	0	0	0	0	0	0	0	0	0	0	0	32	19	4	0	0	0	0	0	0	0	0	0
04/02/2020	Tuesday	Sense	6.5	143	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	17	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	16	16	14	14	0	0	0	0	0	0	0
05/02/2020	Wednesday	Sense	5.7	151	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	17	14	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	12	27	15	13	6	0	3	3	0	0	0	0	0

***Figure 8.2** - Heat Map showing the hours of the day heating is required*

4.1 HEATING SYSTEM INFRASTRUCTURE IN THE BUILDING

4.2 BOILER CONTROL

The building is heated by a heat exchanger getting its heat from a separate heat plant on another part of the site. The building is separated into up to 6 zones (assumed 2 per floor) which are managed by the main Building Energy Management System (BEMS) on site. The valves and pumps are set to run 24/7 on the main BEMS.

Trend BEMS outstation for Jacklin House

Main Switch Panel for Jacklin House

Heat meter used for measuring heat energy going into Jacklin House

Data logger connected to heat meter used to record heat energy data

4.3 ROOM CONTROL BEFORE INSTALLATION

The heat is distributed through the building with modern ¾" & ½" steel pipework from the plantroom and along the corridors and 15mm copper pipework into the rooms. The wet radiators had modern Danfoss TRVs (Thermostatic Radiator Valves) to regulate the temperature in the rooms and appeared to be in good condition.

Examples of existing Thermostatic Radiator Valves (TRVs)

4.4 ROOM CONTROL AFTER INSTALLATION

A Wireless Room Sensor was installed into each room to detect occupancy in the room along with a Genius Radiator Valve. To boost the wireless signal between every 2 rooms a wireless signal booster or Genius Hub was installed into the main riser. See installation drawings for the locations of each component.

Occupancy detectors (Genius Room Sensors) installed into each of the bedrooms	Genius Radiator Valves, replaced existing TRVs
	
Genius Hubs installed into riser cupboard	