ecoterrace Refurbishment Project
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House performance data monitoring - First year interim report

Version 1.2

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Management Summary

This report is an interim report on the results of data monitoring of the thermal performance of two properties from the ecoterraces refurbishment project; 91 London Road and 63 Booth Street, following the first year of occupation. Energy consumption data from periodic meter readings has been analysed and summarised in this interim report.

Initial analysis of the data from both houses indicates that they are not performing as well as predicted by the theoretical SAP calculations based on the design parameters. Both houses have slightly lower hot water energy use to the SAP predictions – Booth Street 7% lower than predicted, London Road 17% lower than predicted. However, both have significantly greater space heating energy use – Booth Street 130% higher than predicted, London Road 107% higher than predicted. An initial possibility for this discrepancy is that the Sunwarm systems are not performing as expected, but due to a lack of monitoring data currently available, it is difficult to identify actual performance or any possible malfunctions of the Sunwarm system.

Nuaire have studied the initial data and suggest that the occupants are mis-using the Sunwarm systems, setting them to heat the properties in the summer and cool them in the winter. Occupant training will be provided to try to ensure this does not happen in the forthcoming monitoring period. It is however recommended that further monitoring equipment measuring energy delivered from the systems is installed. Without this additional data set, if the operator error issue is addressed, but performance of the houses does not significantly improve in the next 12 months, it will not be possible to conclusively prove if this is down to poor performance of the fabric or poor performance of the Sunwarm system.

Although temperature data is being logged for the houses, this data is not presented in this interim report, but will be analysed and presented in the final report alongside the further analysis of the Sunwarm system (assuming additional monitoring data on delivered energy from the Sunwarm system can be provided).

Originally the monitoring project was to have included six occupied properties over a period of two years. However, due to delays in the refurbishment of four of the properties, and hence their un-occupancy, there is currently only data available relating to the two presently occupied properties. As a result of these delays, it has been agreed between Axis Design Consultants (Axis) and Hockerton Housing Project (HHP) to extend the monitoring period by one year (to three years) to provide additional time for the completion and occupancy of the remaining four properties. Monitoring visits however will be reduced in frequency so that the original budget available is sufficient to cover this extended period.

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1. Introduction

Meter readings were taken from both properties on 17/07/08 (handover date) and periodically between then and 29/07/09. The readings taken and annualised consumption figures (for comparison to SAP) are summarised in Table 1 and Table 2 below.

Meter / reading	17/07/08	21/11/08	18/03/09	22/07/09	Total (17/07/08 to 22/07/09)	Annualised
Main Electric (kWh)	21,031	21,585	22,195	22,804	1,773	1,749
Central heating pump (kWh)	69	137	253	330	261	257
Sunwarm pump (kWh)	51	136	187	247	196	193
Immersion heater (kWh)	0	0	0	0	0	0
Lighting (kWh)	110	169	256	328	218	215
Electric shower (kWh)	0	37	64	66	66	65
General ring main (kWh)	9	108	215	328	319	315
Gas (m^3)	659	849	1,471	1,709	1,050	1,036
Gas (kWh)[1]					11,928	11,767
Hot Water (m^3)	0	10.793	21.299	31.000	31.000	30.581

Table 1 - meter readings and annualised consumption for 63 Booth Street

Meter / reading	17/07/08	21/11/08	18/03/09	22/07/09	Total (17/07/08 to 22/07/09)	Annualised
Main Electric (kWh)	2,894	4,211	5,927	7,540	4,646	4,583
Central heating pump (kWh)	26	90	194	268	242	239
Sunwarm pump (kWh)	64	129	183	258	194	191
Immersion heater (kWh)	0	48	48	48	48	47
Lighting (kWh)	71	202	379	493	422	416
Electric shower (kWh)	1	133	369	596	595	587
General ring main (kWh)	17	244	667	1,061	1,044	1,030
Gas (m^3)	4,492	4,706	5,376	5,523	1,031	1,017
Gas (kWh)[1]					11,712	11,554
Hot Water (m^3)	0.579	7.758	14.829	21.340	20.761	20.480

Table 2 - meter readings and annualised consumption for 91 London Road

Table 3 below summarises annual energy use, associated CO_2 emissions[2], running costs[3] and hot water consumption for both properties.

	63 Booth Street	91 London Road
Annual energy use (kWh)	13,516	16,137
Annual CO2 emissions (tCO_2)	3.02	4.18
Annual running costs (£)	£757.68	£1,142.86
Hot water consumption (m^3)[4]	33.16	40.28

Table 3 – annual energy use, CO_2 emissions and running costs

SAP calculations were also provided for each property based on completion of the refurbishment to specification. The key SAP values that will be used in subsequent analysis are summarised in Table 4 below.

[1] *Using average calorific value of 40MJ/m^3 = 11.36kWh/m^3)*
[2] *Based on SAP2005 emissions factors*
[3] *Based on average cost of 4.37p/kWh for gas and 13.92p/kWh for electricity; prices taken from http://www.johnwilloughby.co.uk/ for May 2009*
[4] *These figures vary from those presented in the preceding tables as they also account for hot water use from the electric showers*

SAP value	63 Booth Street	91 London Road
Total floor area (m^2)	76.6	85.2
SAP rating	77	76
Air pressure test ($m^3/hr/m^2$)	7.78	8.1
Energy content of hot water (kWh/yr)	1,801	1,915
Total energy requirement for hot water – incl. losses (kWh/yr)	2,383	2,497
Space heating energy requirement (kWh/yr)	4,691	5,414
Space heating energy requirement ($kWh/m^2/yr$)	61.2	63.5
Primary energy (kWh/yr)	12,370.45	13,772.33
Primary energy ($kWh/m^2/yr$)	161.58	161.57
CO_2 emissions (kg/yr)	2,010.69	2,239.26
CO_2 emissions ($kg/m^2/yr$)	26.26	26.27
Assumed SAP occupancy rate (based on floor area)	2.46	2.71
Actual occupancy	1 adult 1 child	2 adults 2 children

Table 4 - Key SAP parameters used for analysis

The following sections of the report will analyse hot water, space heating, primary energy and CO_2 emissions, comparing the actual values to the SAP predictions, and provide comment on these interim results.

2. Hot water energy requirements

This section analyses the energy requirements to deliver hot water and compares this to SAP predictions, considering the predicted contribution of the Sunwarm system. It also analyses total hot water usage to assess the consumption figures.

2.1. Hot water energy requirements

Hot water to the properties is provided via two sources; a hot water cylinder for delivery of all hot water to the bath, hand basin and kitchen sink; and an electric shower in the bathroom. Hot water is therefore heated by both gas (to the cylinder) and electricity (to the electric shower). In addition, the Sunwarm provides a contribution to the hot water cylinder. As the electric shower is metered separately, it is possible to ascertain the precise energy requirement to deliver hot water to the shower in each property, 65kWh for Booth Street and 588kWh for London Road.

To calculate the energy required to deliver hot water via the cylinder is a more complex process. It is necessary to endeavour to work back from the total hot water consumption, which was metered, and make assumptions about the mains water supply temperature and cylinder temperature. If a cylinder temperature of 60°C and a supply temperature of 15°C are assumed, the resulting temperature uplift required in the cylinder is 45°C. The total volume of hot water consumed is known. It is also known that it takes 1.16W to raise a litre of water through 1°C, and knowing the boiler efficiency, it is then possible to calculate the energy required to provide the hot water consumption via the cylinder. This is illustrated in Table 5 below.

	63 Booth Street	91 London Road
A. Volume of hot water supplied (litres)	31,000	20,761
B. Total energy requirement - 45°C uplift x 1.16W x A (kWh)	1,618.20	1,083.72
C. Less energy supplied from immersion (kWh)	0.00	48.00
D. Net energy required from boiler: B - C (kWh)	1,618.20	1,035.72
E. Boiler efficiency (%)	90.3	90.3
F. Energy requirement from boiler for hot water from cylinder: D / E (kWh)	1,792.03	1,146.98

Table 5 - Hot water cylinder energy requirement

As well as the energy required to heat the hot water in the cylinder, there is additional energy consumed due to losses in the hot water system, namely distribution, storage and primary circuit losses (note that these losses become "useful" incidental gains in the dwelling that therefore reduce space heating energy requirements; see Section 3). It is not possible to measure these losses accurately, so SAP prediction figures are used; these losses are added to the energy requirement calculated in Table 5 above (F) to give a figure for total energy required for the hot water system, as shown in Table 6 below.

	63 Booth Street	91 London Road
A. Energy requirement for hot water from cylinder - F from Table 4 (kWh)	1,792.03	1,146.98
B. Distribution Loss (kWh)	317.82	337.89
C. Storage Loss (kWh)	656.12	656.12
D. Primary circuit loss (kWh)	360.00	360.00
E. Total energy requirement for hot water system: A+B+C+D (kWh)	3,125.97	2,500.99

Table 6 - Hot water system energy requirement

These total energy requirement figures however are still excluding any contribution from the Sunwarm system. To calculate this, it is necessary to rely on SAP predictions as the Sunwarm input to the cylinder is not metered. However, the SAP calculations provided assumed a standard solar hot water system, not the performance of the Sunwarm system, as this is not available to model as an Appendix Q technology in SAP. It is likely that this overstates the contribution to domestic hot water, as the Sunwarm system is unlikely to provide the same energy content to hot water that a normal solar hot water system does.

The reductions in energy requirements for the hot water system due to inclusion of a solar hot water system are twofold; firstly, there is a reduced storage loss as there is a dedicated solar volume in the cylinder no longer heated by the primary circuit; secondly, there is a reduced energy requirement for hot water from the cylinder due to a renewable energy contribution from the solar circuit. The impact of these two factors is illustrated in Table 7 below.

	63 Booth Street	91 London Road
A. Total energy requirement for hot water system: E from Table 5 (kWh)	3,125.97	2,500.99
B. Reduced storage loss due to dedicated solar volume (kWh)	312.44	312.44
C. Solar contribution – prediction from SAP (kWh)	670.46	701.74
D. Revised total energy reqt from boiler for hot water system: A – B - C (kWh)	2,143.07	1,486.81
E. Solar contribution to hot water system: A - D (kWh)	982.90	1,014.18

Table 7 - Hot water system energy requirement including solar contribution

Finally, it is worth comparing these total hot water energy requirements, for both the cylinder and electric shower, to the SAP predictions, as shown in Table 8 below.

	63 Booth Street	91 London Road
A. Calculated total energy reqt from boiler for cylinder: D from Table 6 (kWh/yr)	2,143.07	1,486.81
B. Electric shower energy consumption (kWh/yr)	65.00	588.00
C. Total energy requirement for hot water system: A+B (kWh/yr)	2,208.07	2,074.81
SAP predicted total energy requirement for hot water - incl. losses (kWh/yr)	2,383.17	2,496.71

Table 8 - Total hot water energy requirements compared to SAP predictions

2.1.1. Hot water volumes

The volume of hot water consumed via the cylinder is known as it is separately metered. However, the volume of hot water supplied via the electric shower is unknown; but as the energy consumed by the electric shower is known, and the manufacturer's technical specifications are available, it is possible to calculate approximate water consumption as shown in Table 9 below.

Consumption	7.9kW @ 230v 8.5kW @ 240v
Average flow rate	< 6 litres/min
Average delivery temp	41°C
Average supply temp	15°C
Average temp lift required	26°C

Table 9 - T80xr Eco Shower specifications

If a consumption of 230v/7.9kW is assumed (worst case scenario) it is possible to calculate the total volume of water consumed using the total energy consumption and the total amount of time the shower was used, as illustrated in Table 10 below.

	63 Booth Street	91 London Road
A. Total energy consumption of shower (kWh)	65	588
B. Total time shower used: A / 7.9 * 60 (mins)	493.67	4,465.82
C. Water consumption rate: 7.9 * 1000 / (26 * 1.16 * 60) (litres/min)	4.37	4.37
D. Total water consumption of shower: B * C (litres)	2,157.34	19,515.63
E. Total water consumption of hot water cylinder (litres)	31,000	20,761
F. Total hot water consumption of dwelling: D + E (litres)	33,157.34	40,276.63
G. Number of occupants	2	4
H. Hot water consumption per person per day: F / G / 365 (litres)	45.42	27.59
I. Assumed average shower time (mins)	5	5
J. Number of showers taken in the year: B / I	99	893
K. Amount of water consumed per shower: C * I (litres)	21.85	21.85

Table 10 - Shower usage calculations

3. Space heating energy requirements

The only gas consumption in the properties is for space and water heating; the cookers are electric oven and hob. Therefore since the energy requirement for hot water has been calculated, including an estimated solar contribution, it is possible to use these figures and the total gas consumption for the properties to calculate the energy input for space heating from the gas central heating system. In addition to this there is an energy input to space heating from the Sunwarm system; this is not being metered so we can only go on manufacturer's predicted performance. The manufacturer estimates an energy saving potential for the system of 2,907-3,314kWh/yr. In the calculations below a sense of caution has been used, such that there is an assumption of the worst case scenario of 2,907kWh/yr.

Table 11 below summarises the calculation of an estimated energy requirement for space heating and compares this to SAP predictions.

		63 Booth Street	91 London Road
A.	Total gas consumption (kWh)	11,767	11,554
B.	Boiler efficiency (%)	90.3	90.3
C.	Total energy output from boiler: A * B (kWh/yr)	10,625.60	10,433.26
D.	Energy requirement from boiler for hot water cylinder[5]: F from Table 4 (kWh/yr)	1,792.03	1,146.98
E.	Net energy from boiler to space heating: C – D (kWh/yr)	8,833.57	9,286.26
F.	Assumed contribution of Sunwarm system to total energy requirement (kWh/yr)	2,907.00	2,907.00
G.	Solar (Sunwarm) contribution to hot water: E from Table 6 (kWh/yr)	982.90	1,014.18
H.	Total space heating energy requirement (excl. passive gains): E+F-G (kWh/yr)	10,757.67	11,179.10
I.	SAP predicted space heating requirement (kWh/yr)	4,691.00	5,413.75
J.	Total space heating requirement (kWh/m^2/yr)	140.44	131.21
K.	SAP predicted space heating requirement (kWh/m^2/yr)	61.20	63.50
L.	Space heating energy requirement as a % of SAP estimates: H/I (%)	229.48	206.63

Table 11 - Estimated total energy requirement for space heating

[5] *This does not include the energy to losses in the HW system as these are effectively inputs to the space heating system*

4. Total energy, primary energy and CO_2 emissions

4.1. Total energy consumption

The Energy Saving Trust (EST) publish average total energy consumption figures for typical house types, so it is interesting to compare the ecoterrace data to these data; as illustrated in Table 12 below.

Property	Property Type	Total annual energy consumption (kWh)	EST average for same property type (kWh)[6]	ecoterrace property reduction (%)
63 Booth Street	3-bed mid-terrace	13,516	18,572	27.22
91 London Road	3-bed end-terrace	16,137	22,902	29.54

Table 12 - Total annual energy consumption

4.2. Primary energy and CO_2 emissions

It is possible to calculate an annual primary energy use and CO_2 emissions for the properties from the gas and electricity consumption figures, as illustrated in Table 13 below.

	63 Booth Street	91 London Road
A. Total gas consumption annualised (kWh/yr)	11,767	11,554
B. Primary energy factor for mains gas (from SAP2005)	1.15	1.15
C. Total primary energy from gas: A*B (kWh/yr)	13,532	13,287
D. Total electricity consumption annualised (kWh/yr)	1,749	4,583
E. Primary energy factor for mains electricity (from SAP2005)	2.8	2.8
F. Total primary energy from electricity: D*E (kWh/yr)	4,897	12,832
G. Total primary energy for dwelling: C+F (kWh/yr)	18,429	26,119
H. Total primary energy for dwelling (kWh/m^2/yr)	240.59	306.56
I. CO_2 emissions factor for mains gas (from SAP2005) (kgCO_2/kWh)	0.194	0.194
J. CO_2 emissions factor for mains electricity (from SAP2005) (kgCO_2/kWh)	0.422	0.422
K. Total CO_2 emissions for dwelling: A*I + D*J (kgCO_2/yr)	3,020.88	4,175.50
L. Total CO_2 emissions for dwelling (kgCO_2/m^2/yr)	39.44	49.01

Table 13 - Primary energy and CO_2 emissions

SAP also estimates primary energy use and CO_2 emissions. However, SAP only estimates energy use for space heating, water heating and lighting (energy use for pumps and fans associated with space and water heating is also incorporated). Therefore to compare the ecoterrace property data in Table 13 above to SAP, it is necessary to make some adjustments. For space and water heating this is possible, as this is accounted for by all the gas consumption in the property, and the electric shower and immersion energy consumption, which are both separately metered. For pumps, fans and lighting, these are also all separately metered (central heating pump; Sunwarm pump; and lighting circuit). The relevant figures are given in Table 14 and Table 15 below.

[6] *EST Information Team; 19/07/2006*

		63 Booth Street	91 London Road
A.	Total primary energy from gas (kWh/yr)	13,532	13,287
B.	Total primary energy from electric shower (kWh/yr)	182	1,644
C.	Total primary energy from immersion (kWh/yr)	0	132
D.	Total primary energy for space and water heating: A+B+C (kWh/yr)	13,714	15,063
E.	Total primary energy for pumps and fans (kWh/yr)	1,260	1,204
F.	Total primary energy for lighting (kWh/yr)	602	1,165
G.	Total primary energy for space & water heating, lighting, pumps & fans: D+E+F (kWh/yr)	15,992	17,432
H.	SAP estimated primary energy (kWh/yr)	12,370	13,772
I.	Total primary energy for space & water heating, lighting, pumps & fans (kWh/m^2/yr)	208.77	204.60
J.	SAP estimated primary energy (kWh/m^2/yr)	161.58	161.57
K.	Primary energy requirement for space & water heating, lighting, pumps & fans as a % of SAP estimates: G/H (%)	129%	127%

Table 14 - Primary energy for SAP comparison

		63 Booth Street	91 London Road
A.	Total CO_2 emissions from gas ($kgCO_2$/yr)	2,282.80	2,241.48
B.	Total CO_2 emissions from electric shower ($kgCO_2$/yr)	27.43	247.71
C.	Total CO_2 emissions from immersion ($kgCO_2$/yr)	0	19.83
D.	Total CO_2 emissions for space and water heating: A+B ($kgCO_2$/yr)	2,310.23	2,509.02
E.	Total CO_2 emissions for pumps and fans ($kgCO_2$/yr)	189.90	181.46
F.	Total CO_2 emissions for lighting ($kgCO_2$/yr)	90.73	175.55
G.	Total CO_2 emissions for space & water heating, lighting, pumps & fans: D+E+F ($kgCO_2$/yr)	2,590.86	2,866.03
H.	SAP estimated CO_2 emissions ($kgCO_2$/yr)	2,010.69	2,239.26
I.	Total CO_2 emissions for space & water heating, lighting, pumps & fans ($kgCO_2$/m^2/yr)	33.82	33.64
J.	SAP estimated CO_2 emissions ($kgCO_2$/m^2/yr)	26.26	26.27
K.	CO_2 for space & water heating, lighting, pumps & fans as a % of SAP estimates: G/H (%)	129%	128%

Table 15 – CO_2 emissions for SAP comparison

5. Commentary

5.1. Hot Water

In terms of hot water energy consumption, the houses are performing slightly better than SAP predictions, with Booth Street using 7% less energy for hot water and London Road 17% less. However, hot water consumption is a factor of occupancy, and Booth Street has lower occupancy than SAP assumes (2 occupants compared to a SAP assumption of 2.46) whilst London Road has higher occupancy (4 compared to a SAP assumption of 2.71). Therefore when this is taken into account, Booth Street is perhaps not performing as well in relation to hot water as the gross figures suggest, whereas London Road would seem to be performing much better.

In relation to Booth Street it should however be noted that the resident was unable to use the shower for some time as the electric shower had been incorrectly plumbed onto the hot water feed from the cylinder, not the mains cold water feed (this has now been corrected). This would have meant hot water being delivered that was far too hot to shower in. This therefore meant that the resident was forced to take baths, which would significantly increase the volume of hot water, and hence energy, used. It is therefore surprising to see (relatively) significant energy consumption from the electric shower. However, in November 2008 the hot water cylinder thermostat was recorded as being set at 43^{o}C, at which temperature the shower would be useable; this is lower than recommended though, and it can only be assumed that subsequently this was adjusted to the recommended level of 60^{o}C, at which point the shower would have become unusable. It is worth noting that between March and July 2009 there was only 1kWh of consumption from the electric shower, so it is fair to assume the cylinderstat temperature was adjusted at some point soon after the March 2009 reading.

5.2. Space Heating

The space heating energy use in both houses is significantly higher than the SAP predictions; Booth Street by 130% and London Road by 107%. It also needs to be noted that the time for which the central heating is used in both houses, based on occupant feedback, is a lot less than the SAP assumed standard heating pattern, which would suggest performance of the houses is even poorer. The Booth Street residents stated that central heating is used as needed, and during monitoring visits there was no evidence of higher than normal temperatures (the internal temperature being 17^{o}C on one visit). The London Road residents stated that the heating was used as needed between July to November and April to July, and set to timed for the period November to April. During the timed period, the heating was set to be on for four hours per day. For reference, SAP assumes 9 hours per day for weekdays and 16 hours per day for weekends.

It is doubtful that the houses are underperforming thermally to the extent indicated by these figures, assuming they were refurbished to specification; this then brings into question the Sunwarm system, and whether this is in fact having a positive or detrimental impact on the performance of the houses.

Due to a lack of detailed monitoring data for the Sunwarm systems, it is difficult to isolate its impact at this stage. This will be an area of focus for subsequent monitoring periods.

5.3. Total energy, primary energy and CO_2 emissions

In terms of total energy consumption, the two houses are both performing significantly better than the EST guideline for similar property types in the existing housing stock; Booth Street by 27% and London Road by 30%. The aim of the refurbishment was to achieve the equivalent of Code for Sustainable Homes level 4 (Ecohomes Excellent), which is a 44% reduction on the Target Emissions Rate (TER) in new build. The performance, therefore, falls well short of this 44% reduction target.

In both primary energy and CO_2 emissions terms, the houses are again performing poorer than the SAP predictions, around 30% worse for both houses when the total consumption is adjusted to reflect just the SAP predicted consumption for electrical energy (lighting, pumps and fans). When looking at the constituent parts of this total, both houses use less primary energy for pumps and fans – Booth Street 61% less and London Road 66% less; this may be misrepresentative though, as the SAP calculations were done using the standard SAP defaults for the ventilation system, which, in our experience, leads to excessive electrical consumption being predicted. (The predicted electrical consumption figures for ventilation were 915.58kWh for Booth Street and 1,016.27kWh for London Road; actual consumption of the Sunwarm units was 193 and 191kWh respectively).

Looking at lighting alone, Booth Street used 38% less energy than SAP predicted; London Road used 3% more. SAP lighting calculations are for fixed light fittings only; it is not known how much energy was used in either house for portable lighting (table lamps and standard lamps), if any. This may mean the houses actually required more energy for lighting than the figures suggest.

6. Conclusions

The houses are clearly not performing as well as predicted based on design, and the evidence suggests that it is the space heating demand that is causing the significant variance. The question therefore is whether this is an under performance of the thermal insulation; an under performance of the central heating system; an under performance of the Sunwarm system; or indeed a combination of all three.

It is suspected that the most likely reason is a poor performance from the Sunwarm system. Nuaire have identified that this could be a result of user error, and this will be addressed by occupant training in the use of the systems. Further analysis of temperature data and Sunwarm performance (if provided) will then be carried out in subsequent monitoring periods to investigate this issue further. Results will be presented in the end of monitoring report. Additional data for the Sunwarm systems that would enable more accurate analysis to be completed would include flow rates and heat meters. This is strongly recommended as without it, it will be difficult to conclusively prove where responsibility for the poor performance of the houses lies, if this is still evidenced.