Building Performance Evaluation: In-use Post Occupancy Evaluation – a Welsh Case Study

Aberfawr Terrace, Abertridwr, Wales

Building Better Buildings

3rd February 2016

Dr John Littlewood*^

***Director* – Sustainable Construction Monitoring & Research Ltd**

^Head of the EBERE group, Cardiff Metropolitan University

scmr2410@gmai.com and jlittlewood@cardiffmet.ac.uk

Project partners

United Welsh Housing Association (BPE grant winner), Caerphilly, Wales

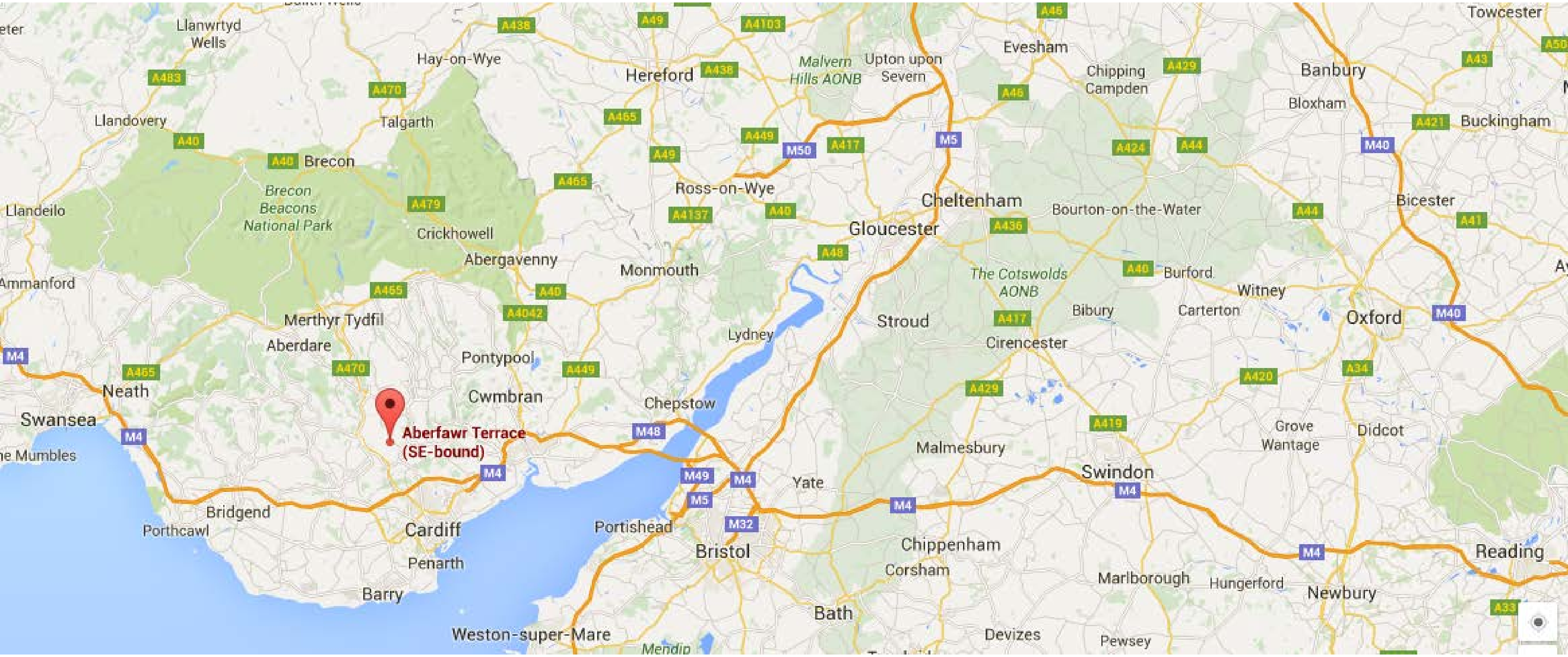
InnovateUK

Sustainable Construction Monitoring & Research Ltd, Dinas Powys, Wales

Cardiff Metropolitan University (2011-2012), Cardiff, Wales

Thanks to: Richard Mann, Ivan Smallwood, Mat Colmer, Alex Moody

Introduction – Aberfawr Twerrace, Abertridwr



Altitude is 155 metres above sea level, side of a river valley.

Orientation is north/south (flats) and west/east (houses).

Designed and constructed as a package deal with a Welsh contractor.

Occupied from December 2010: nine single-storey flats, four two-storey houses and one fly-over maisonette.

BPE study: two flats (single occupancy), one two-storey house, two bedrooms (2 adults/1 child) and one two-storey house, three bedrooms (multiple occupancy).

Key questions: Design Intent Vs Actual Building Performance.

1. How does timber frame versus brick/block construction effect dwelling internal comfort conditions, space heating energy use and carbon emissions?

2. Do NIBE EASHPs lead to high energy usage and associated costs/carbon emissions for space/water heating, and how to occupants engage with such systems and their controls.

3. How can the handover/tenant education be developed and used on other schemes and can any lessons be learnt from the contractor's direct supply approach?

4. How do air tightness values that exceed the maximum optimum of 3 $m^3/h.m^2$, at 4.8 $m^3/h.m^2$ (houses) affect the use of the EASHPs.

5. UW wishes to understand whether it needs to fundamentally overhaul its design, procurement, commissioning and hand-over strategies; by stipulating more exacting design, construction, commissioning and operational standards.

(Littlewood et al, 2014)

Introduction – Aberfawr Terrace: Dwellings

- All houses CfSH level 3+ and flats CfSH level: 4, latterly DECC grant during construction in 2010.

- Flat construction - 0.28, 0.1 and 0.1 W/m²K U values for exterior walls, roof and ground floor, timber frame, sheeps wool insulation, cedar clad, triple glazing, 1 kW PV;
- House Construction: 0.18, 0.1 and 0.2 W/m²K U values for exterior walls, roof and ground floor; brick/block cavity construction, double glazing, no PV.

- Heating/Ventilation: electric only: NIBE EASHPs + underfloor heating


(Littlewood et al, 2014)

Some key Findings affecting SAP calculations

- Incorrect review of installed components in 2010, e.g. windows in flats: uPVC wood grain mimic finish not Jeld Wen Dream Vu softwood windows as specified; & higher performance included within the 2010 SAP calculations than were installed.

- PVs specified as installed within houses, but not installed until 2012, two years post completion.

- No air tightness certificates and incorrect values:

	As Built Air Permeability - 2010	BPE Test Air Permeability 2014	Difference
Flat	2.9 $m^3/(h.m^2)$@50Pa	3.72 $m^3/(h.m^2)$@50Pa	+0.82 $m^3/(h.m^2)$@50Pa
House	4.8 $m^3/(h.m^2)$@50Pa	8.8 $m^3/(h.m^2)$@50Pa	+4.00 $m^3/(h.m^2)$@50Pa

- No validated or commissioning data sheets for installed systems
- No maintenance of systems: 2010 and 2012, + occupants unaware

(Littlewood & Smallwood, 2015)

Some key Findings affecting SAP Calculations 2

Unwanted Air Leakage	House	Flat
Bathroom window frame – ground floor cloakroom/bathroom	√	√
Bathroom window sill		√
Boxing to soil vent pipe - bathroom		√
Boxing to soil vent pipe - kitchen		√
Wall to floor junction – storage room on party wall with 1st floor flat stairwell.		√
Living room window frame		√
Loft hatch - landing	√	√
Consumer unit - hall	√	
PV meter – hall	√	
Grommets on toilet waste pipe – 1st floor bathroom	√	
Ceiling – 1st floor bathroom	√	
Ducting through ceiling; Void behind 1st floor storage cupboard, not identified on any drawings.	√	
Exterior wall penetration – kitchen*	√	
Ceiling – ground floor lounge	√	
*For the installation of a tumble dryer (not installed)		

(Littlewood & Smallwood, 2015)

SAP-ASSESSED AND ACTUAL MONITORED ENERGY PERFORMANCE: FLAT + HOUSE

Energy	2010-SAP	2014-SAP	July 2013-June2014 Monitored data
Primary energy (kWh/yr)	8579.94	10874.29	4143.33*
Primary Energy (kWh/m²/yr)	107.76	136.58	53.05
Heating Energy (kWh/yr)	6880.97	8018.00	4009.8
Heating Energy (kWh/m²/yr)	86.42	101.37	50.69

Energy	2010-SAP	2014-SAP	July 2013-June2014 Monitored data
Primary energy (kWh/yr)	3836.82	5184.90	1968.61*
Primary Energy (kWh/m²/yr)	78.69	106.36	41..66
Heating Energy (kWh/yr)	4932.62	6353.55	1628.50
Heating Energy (kWh/m²/yr)	101.16	130.33	34.47

SAP over predicts energy use, thus inaccurate. But, the heating systems in both properties were commissioned incorrectly, impacting upon energy usage/heating efficiencies.

The SAP Adjusted Internal Comfort temperatures of 19.32°C/19.66°C (f/h) as determined by 2010-SAP notably lower than the 2014-SAP calculated temperature of 21.0°C derived for both.

Some key Findings from the System Inspection & occupant Interaction

- The EASHP heating-curve 'set-point' for both dwellings was set to the manufacture's settings for radiators not under-floor heat output sources.

- In the house, the 'selected' heating-curve and heat-supply output was set for climates akin to Sweden with external temperatures of -20^{o}C and the Swedish language.

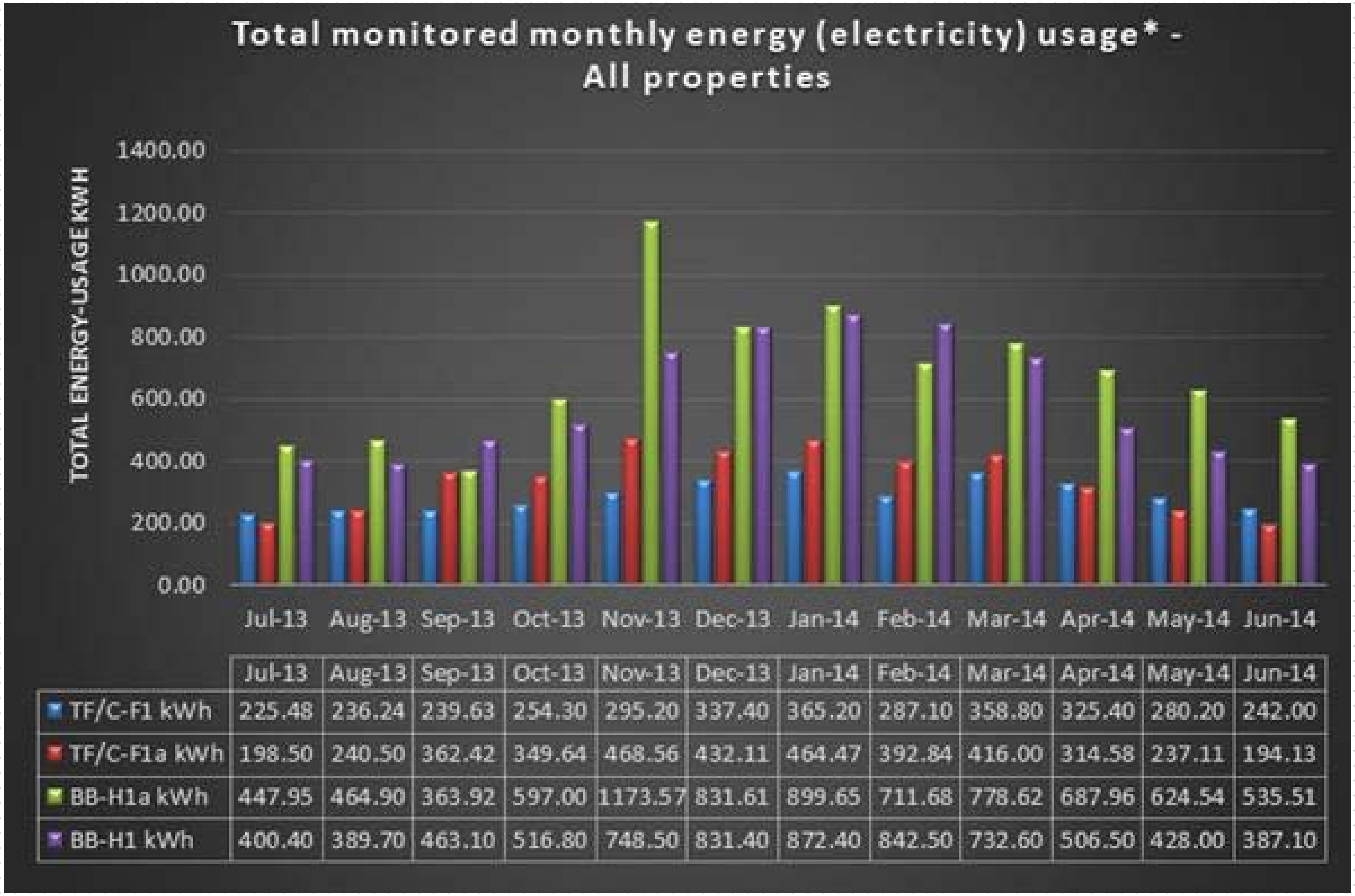
- Ceiling terminals for extracting air from some rooms: inspected as altered and also dust, grease and particulate matter was found to be blocking the ducting, both.

- Monitored data indicates that overall the flat never sustains the SAP-Adjusted internal comfort temperature suggesting little heat is recovered through the ceiling ducts & underfloor heating was faulty.

- Both house and flat: overall air flow, (m^3/h^{-1}), is 35% higher & 26% lower in house/flat than the manufacture's recommendations: affecting indoor air quality, heating demands and heat recovery.

- Both house and flat: occupants 'fail' to understand the 'nuances of the installed EASHPs/under-floor heating, operated as 'turn-on/off' & timed – even after repeated instructions during handover, and the BPE project. Filter cleaning problem.

Some key Findings Monitoring – Energy Usages all dwellings



	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14
TF/C-F1 kWh	225.48	236.24	239.63	254.30	295.20	337.40	365.20	287.10	358.80	325.40	280.20	242.00
TF/C-F1a kWh	198.50	240.50	362.42	349.64	468.56	432.11	464.47	392.84	416.00	314.58	237.11	194.13
BB-H1a kWh	447.95	464.90	363.92	597.00	1173.57	831.61	899.65	711.68	778.62	687.96	624.54	535.51
BB-H1 kWh	400.40	389.70	463.10	516.80	748.50	831.40	872.40	842.50	732.60	506.50	428.00	387.10

Occupancy patterns are linked to higher energy usage as are greater exposed facades

Some key Findings Monitoring vs SAP – Heating: Flat & House

Energy	2010-SAP	2014-SAP	Monitored data	% monitored value of SAP value	
Total Heating Energy Usage (kWh/yr)*	2051.63	2307.25	1628.50	79.37	70.58
S/Heating Energy Outputs (kWh/yr)	1387.70	3149.83	1244.00#	89.64	60.51
H/W Heating Energy Outputs (kWh/yr)	2111.63	1533.46	342.00#	16.20	22.30

Energy	2010-SAP	2014-SAP	Monitored data	% monitored value of SAP value	
Total Heating Energy Usage (kWh/yr)*	2858.93	3376.83	4009.80	140.26	118.74
S/Heating Energy Outputs (kWh/yr)	2417.51	6463.01	2046.00#	84.63	31.65
H/W Heating Energy Outputs (kWh/yr)	2608.35	1855.38	2558.00#	98.07	137.87

*heating values includes energy usages for heat pump, immersion and, pumps, fans and controls.
#monitored heating, space and hot water, energy outputs (NOT USAGE).

(Littlewood & Smallwood, 2015)

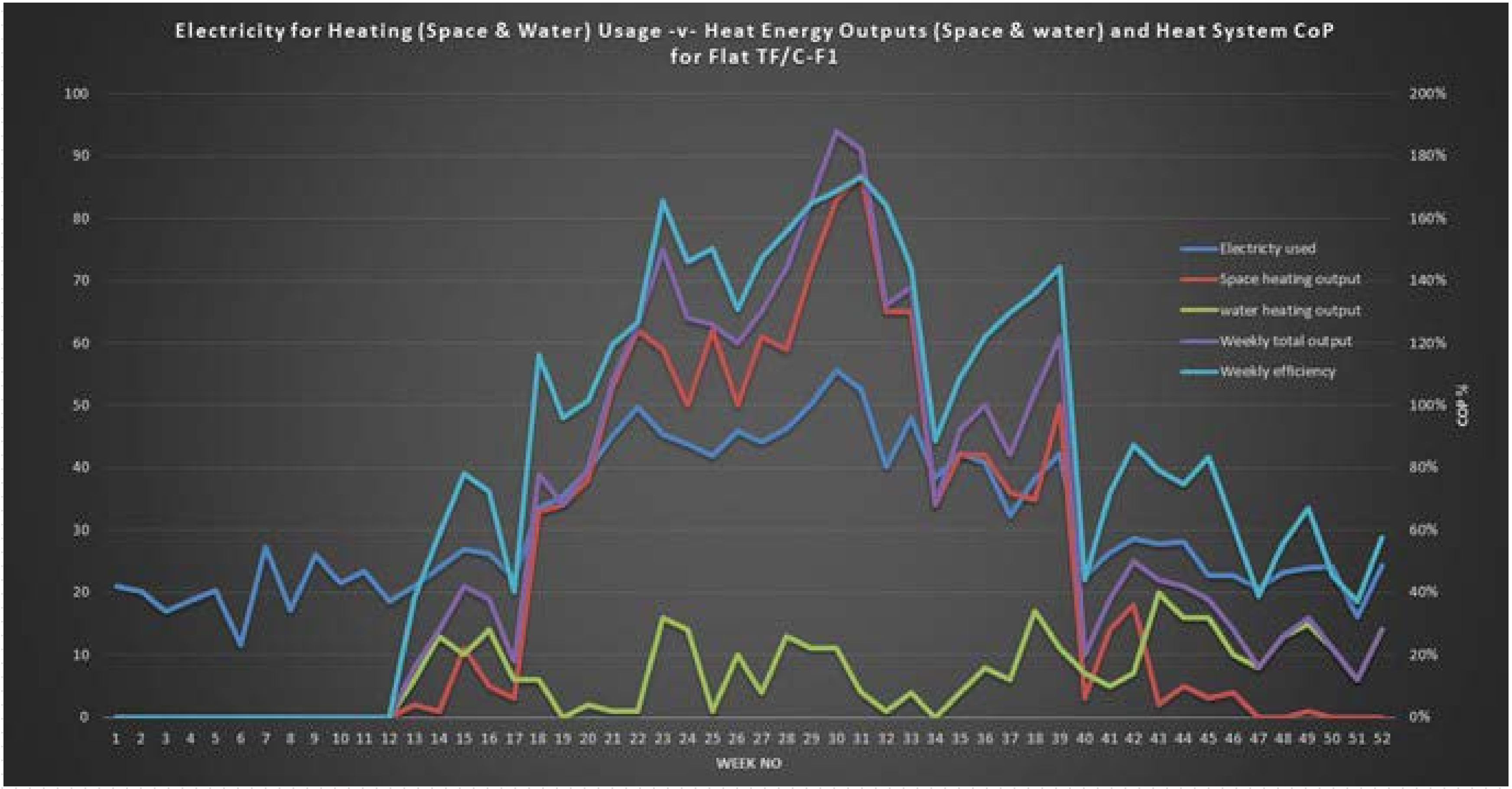
Key conclusions from Monitoring energy usage

Within the two fully monitored construction-types noticeable issues impact on the assessment of the overall building performance, including; building fabric weaknesses, incorrect commissioning, operating and maintenance of the installed heat-energy systems.

The observed differences between the SAP and monitored data for total and space-heat energy-output cannot be fully accounted for by the aforementioned building fabric deficiencies and/or heating systems inefficiencies as alluded to through-out.

It is evidential that occupancy patterns and behaviour strategies impacts on energy usage, particularly the turn on/turn off of the EASHP approach.

Some key Findings Monitoring – EASHP COP: Flat

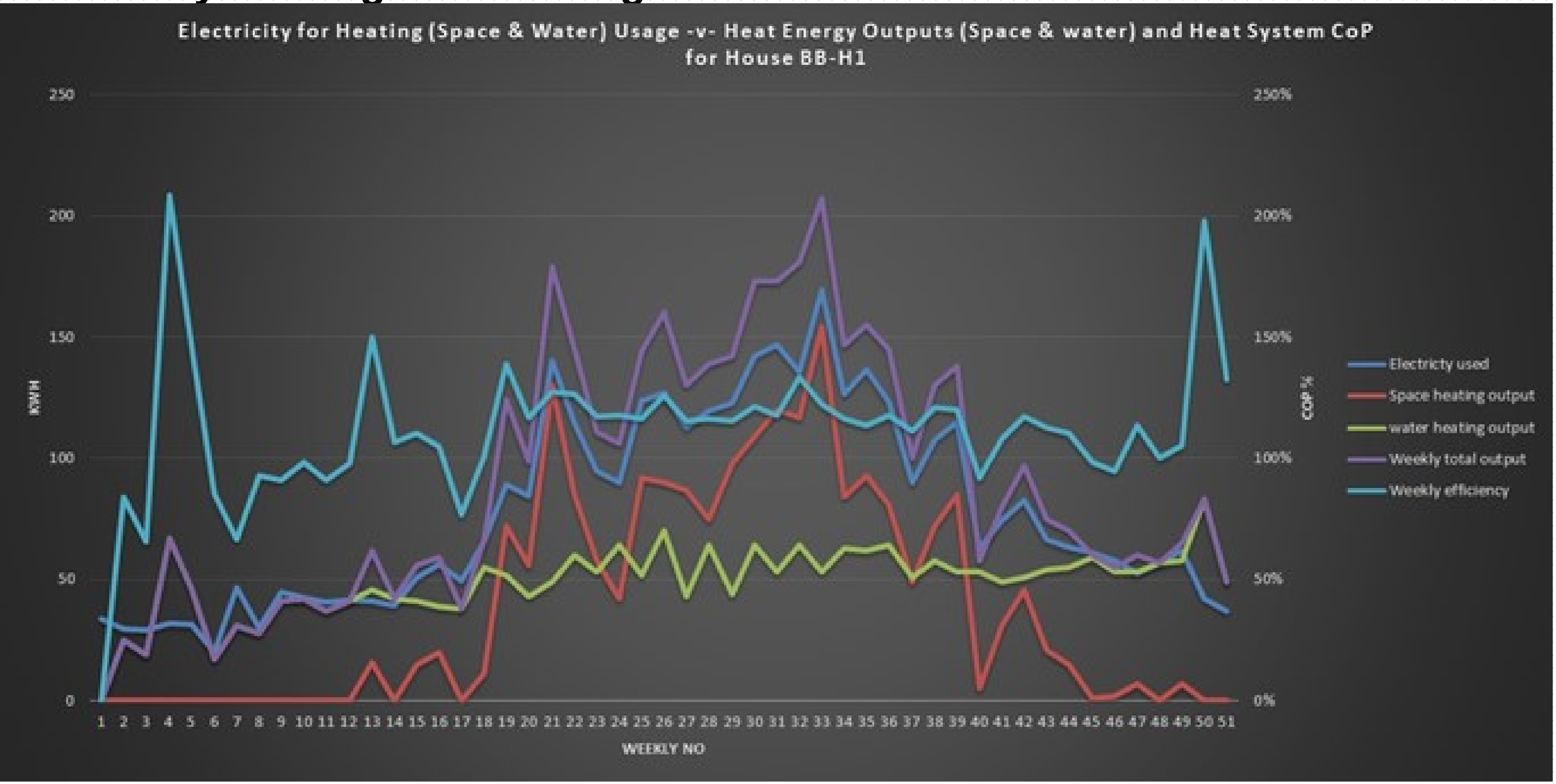


week 1-12 represent non-heating demand July–September, overall trend: Total Electricity usage, (dark blue), Total Heat output, (purple) typical of increasing/decreasing heat outputs for the SAP heat demand 10-05

NIBE SYSTEM	NIBE-Published CoP	Derived CoP Maximum (Difference)	Derived CoP Minimum (Difference)
Fighter 205/Flat TF/C-F1	3.15	1.733 (-1.417)	0.370 (-2.78)

SCMR Director: Dr John Littlewood, scmr2410@gmail.com

Some key Findings Monitoring – EASHP COP: House



The Derived CoP values are unusual. Notable, the maximum Derived CoPs occur in the SAP non-heating period; July to September, before the first heating period begins.

NIBE SYSTEM	NIBE-Published CoP	Derived CoP Maximum (Difference)	Derived CoP Minimum (Difference)
Fighter 360P	3.40	2.09 (-1.31)	0.655 (-2.75)

Key conclusions from Monitoring EASHPs

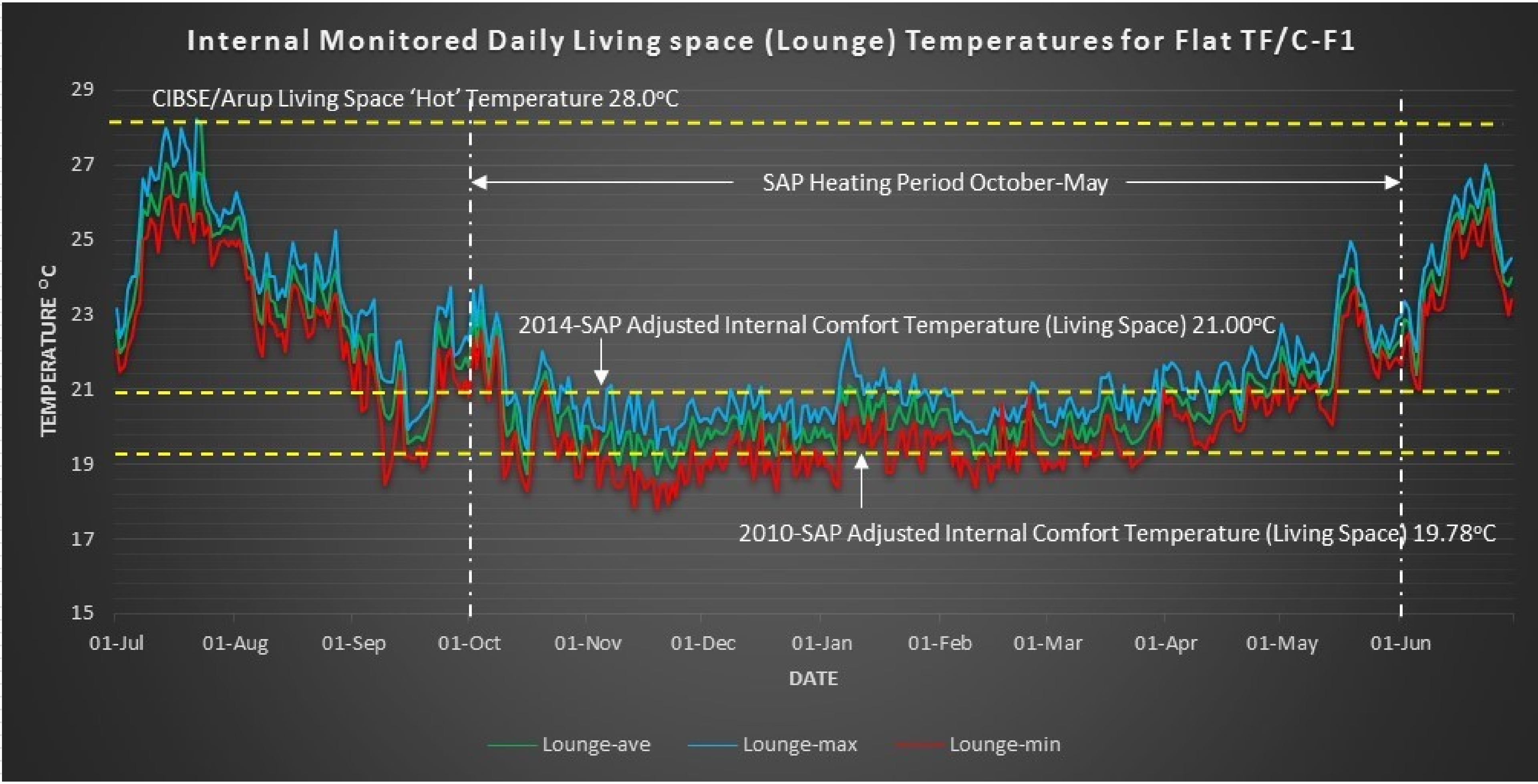
The incorrect testing/commissioning of the installed heating and ventilation systems means that, regardless of other external factors, the installed EASHP-systems cannot operate to the manufacture's efficiencies.

No conclusions can be drawn of the effectiveness of the installed technologies in reducing energy consumption, associated emissions and operating costs.

This BPE study highlights the existence of a 'knowledge gap' within the end-users, occupants have developed behaviour strategies in the provision of their internal comfort levels and environmental conditions using the installed heating and ventilation.

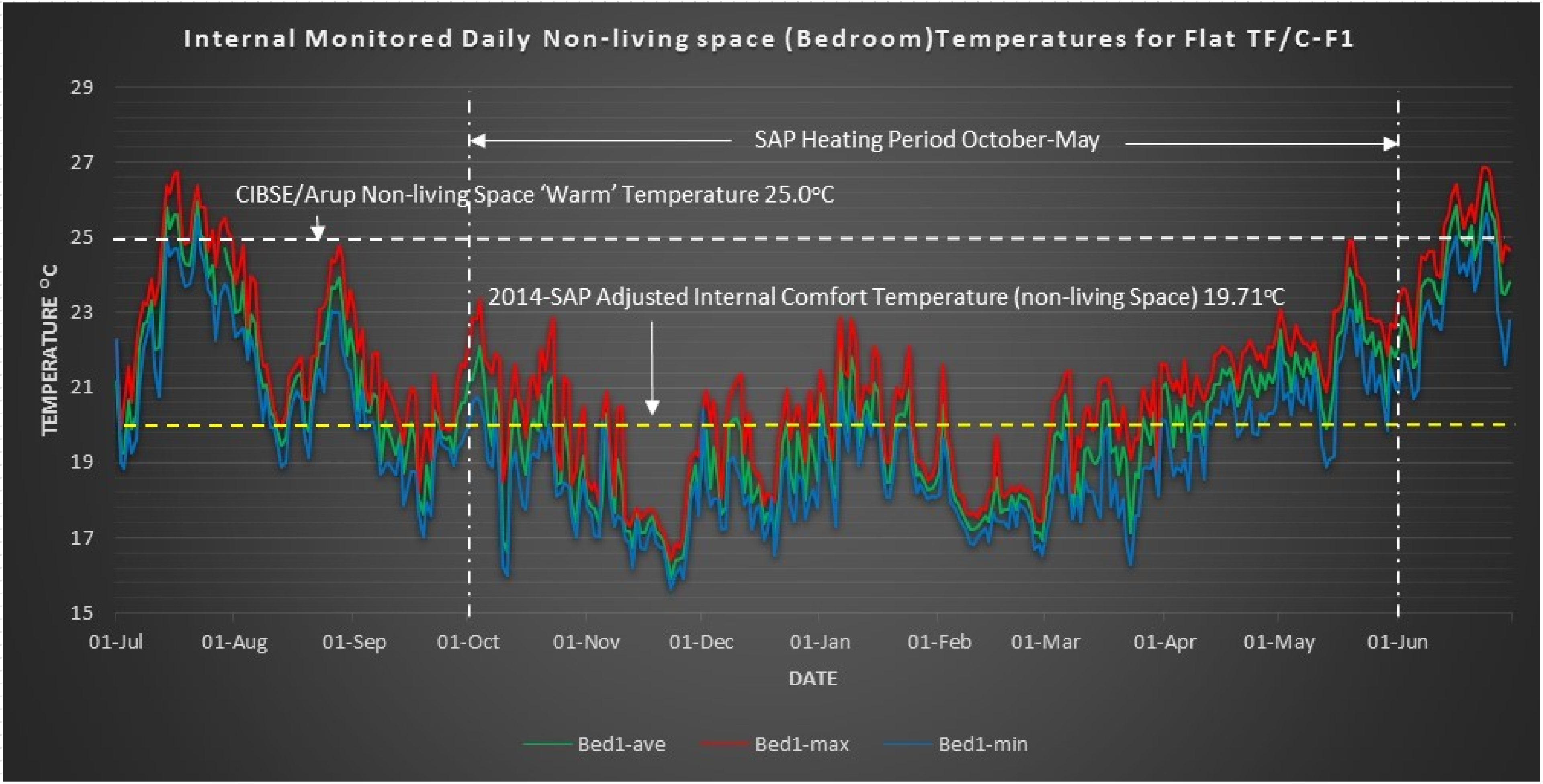
Certain actions have a significant detrimental effect which further exasperate the effectiveness of the installed systems and are also reflective of the barrier between users and new technologies in that there 'appears' to be evidence that older technologies; central heating and extractor fans for example, provide a greater feeling of control of the end-user internal environments.

Some key Findings Monitoring – Environmental Conditions Flat



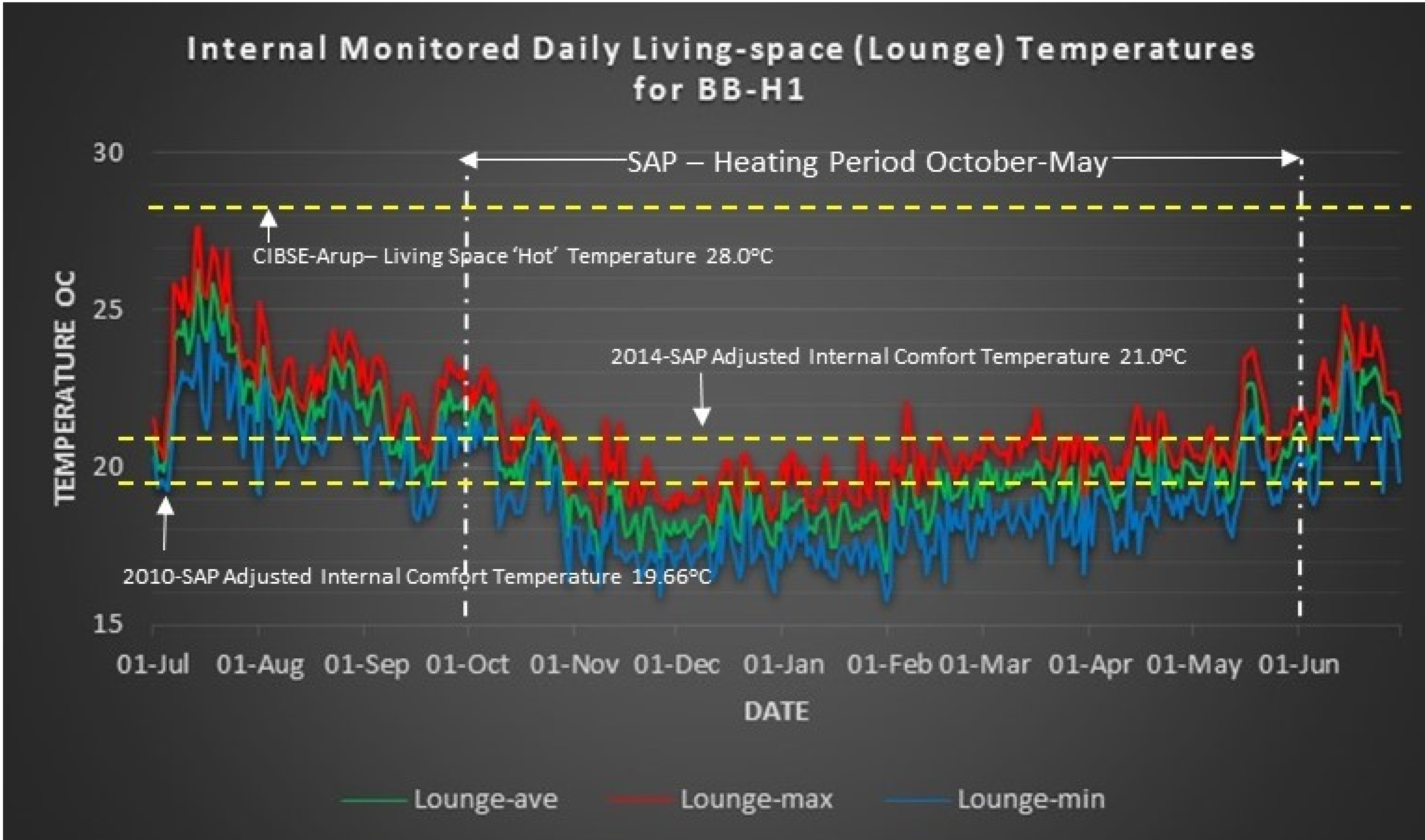
Underheating/Overheating

Some key Findings Monitoring – Environmental Conditions Flat2



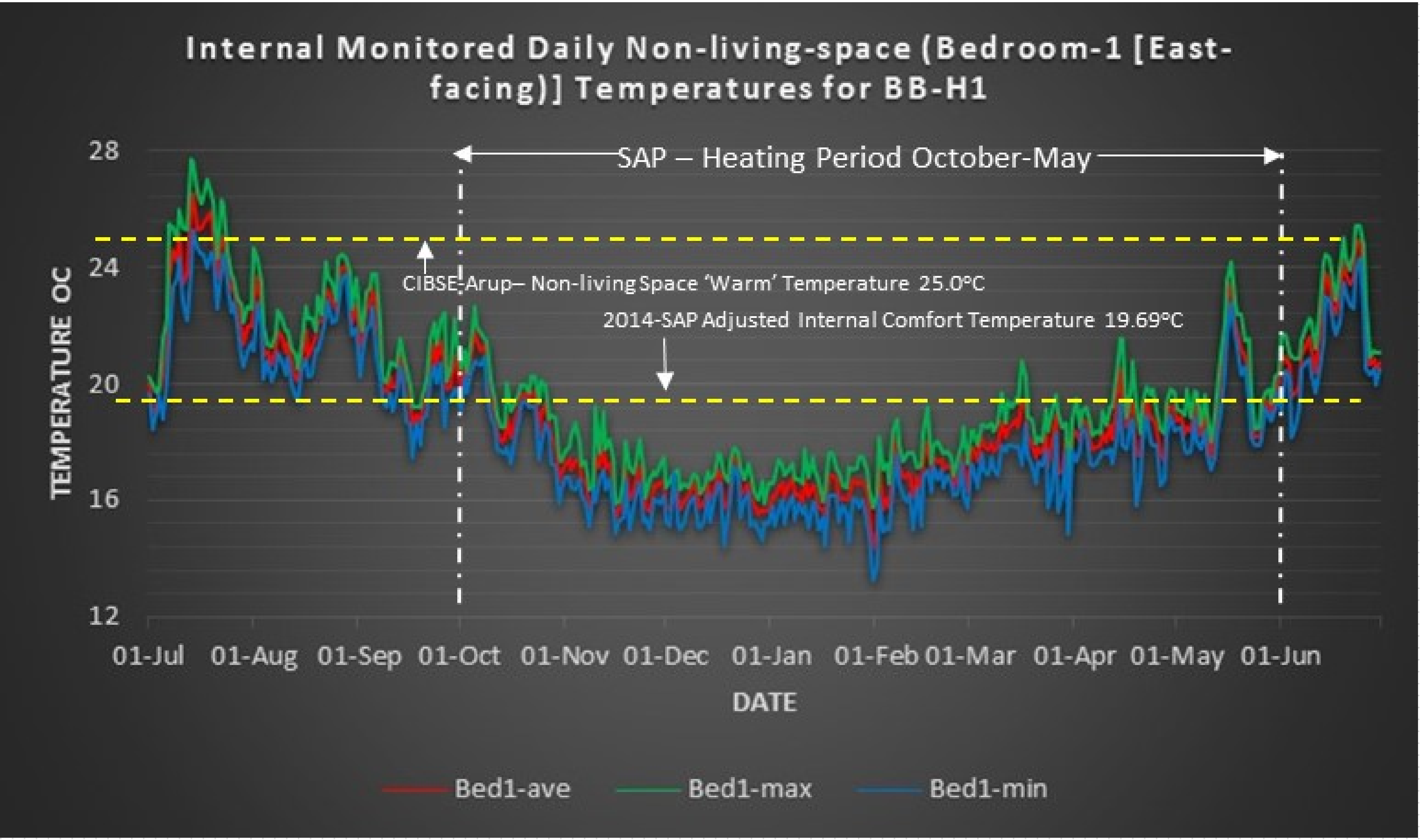
Underheating/Overheating

Some key Findings Monitoring – Environmental Conditions House



Underheating/Overheating

Some key Findings Monitoring – Environmental Conditions House 2



Underheating/Overheating

Key conclusions from Monitoring Environmental conditions

- Generally inefficient heating output during the heating period from the EASHPs; exacerbated by occupant use of turn on/turn off of heating. Plus, excessive air permeability within house.

- Without the necessary testing, commissioning and subsequent maintenance of the installed NIBE systems it is inferred that the original design intents, which include both the space-heat demands and the ventilation requirements, can never be met regardless of the reported building fabric and occupancy interventions.

- Similarly, the installed systems would not be able to achieve the efficiencies and effectiveness, cost-benefits, internal temperatures and emission savings of the manufacture's technical statements; these arguments are furthered in section eight below.

SCMR Director: Dr John Littlewood, scmr2410@gmail.com

Key Messages

It is clear that the Design and Build and complete package deals, where the contractor retains the majority of the control until handover, may not be suitable for innovative developments using non-standard construction and systems.

The local authority building control must be active in checking construction compliance on site throughout the process until handover, to ensure responsible and true certification. In addition, the NHBC should also take an active part in this process to ensure that construction and installation meets design intents.

The 'Performance Gap' does not stop post-construction; the processes of an informed handover to future occupants and a robust maintenance management programme is need to ensure that the properties are used and maintained as to the original design intents if energy-efficiency and low-costs benefits are to be continually realized.

Building performance in the life-time of a property is ultimately dependent upon the occupier's ability and willingness to use the building and systems to the original design intents and not rely on others to manage this on their behalf.

The BPE study further highlights the current serious questions within sustainable construction as to applicability/enforceability of the current raft of regulations, policies and standards so that design intents are translated into actual long-term usable benefits.

Lessons embedded at United Welsh

During the BPE project, a dedicated staff member was employed within the development team for managing handover of projects to tenants;

Post BPE study, a new development inspector (clerk of works) was employed to specifically focus upon construction performance during the build stage, with both architectural design and construction experience

SCMR Ltd retained post BPE to offer guidance on compliance testing: air test observations, conducting independent air tests, thermography tests, and whole dwelling smoke tests.

REFERENCES

LITTLEWOOD, J. R. DAVIES, G, J. SMALLWOOD, I. 2014. Energy and Environmental Performance of the Abertridwr Community – First Winter Season. *Energy Procedia*, Volume 62, December, Pages 532–542.

LITTLEWOOD, J. R. SMALLWOORD, I. 2015. Testing Building Fabric Performance and the Impacts Upon Occupant Safety, Energy Use and Carbon Inefficiencies in Dwellings. *Energy Procedia*, Volume 83, December, Pages 454-463.

THANK YOU FOR YOUR ATTENTION

ANY QUESTIONS