Avante Housing Development

Innovate UK project number	450011 (related to 450077 and 450078)
Project lead, authors, and client	School of the Built Environment, Oxford Brookes University, CA Sustainable Architecture, and Four Walls for Crest Nicholson PLC
Report date	August 2015
InnovateUK Evaluator	Tom Kordel (Contact via www.bpe-specialists.org.uk)

No of dwellings	**Location**	**Type**	**Constructed**
150 (2 plots sampled)	Maidstone, Kent	Private & social housing	2007 - 2011
Area	**Construction form**	**Space heating target**	**Certification level**
85.2 m^2 (Sample)	Timber panel	52.3 kWh/m^2 per annum	EcoHomes (Excellent)

Purpose of evaluation

The two-storey houses and flats over garages were a mixture of open-market, shared ownership and affordable houses. The houses were equipped with Mechanical Ventilation with Heat Recovery (MVHR) and used a structurally insulated timber panel system (SIPS) construction. The study investigated the as-built performance of the building compared with design predictions, the interaction of residents with their homes, and their comfort through the seasons, and the potential for improvements in the developer's business processes to produce better performing homes.

Design energy assessment	**In-use energy assessment**	**Sub-system breakdown**
Yes (SAP 2005)	No	No

Homes were constructed using SIPs and were designed for high tightness and thermal insulation. Simple gas central heating systems with an MVHR unit were installed. The study covered final construction stages and early occupancy and therefore no monitoring of operational energy use was completed and therefore findings in relation to the energy strategy are limited. The SIP panels were believed to function well, but analysis of the party wall in the co-heating test showed significant heat loss. It was concluded that the cavity between the house walls was not properly filled with insulation and sealed, leading to air movement and heat loss from the cavity. The airtightness was shown to be 5.82 m^3 (m^2.h), above the target of 5 m^3 (m^2.h). The MVHR unit was tested through on site flow rate measurements and was found to be significantly lower than that specified by the system designer. The usability of the heating and hot water controls was not intuitive and users needed instructions to use it properly. The MVHR system was not intuitively understandable, labelling and annotation was confusing, and the control panels difficult to use.

Occupant survey type	**Survey sample**	**Structured interview**
Domestic BUS	42 of 135 (31% response rate)	N/A

Generally, the occupants were very satisfied with the housing development overall and were particularly appreciative of the location, spatial, layout and appearance of the homes. However, a number of issues were identified in relation to usability and environmental conditions.

Content

Acronyms

BPE: Building Performance Evaluation. Typically a study carried out which assesses the performance of a building through its lifecycle compared to design intentions.

BUS: Building Use Studies. Organisation promoting questionnaires for BPE.

HLC: Heat loss co-efficient. The heat loss from the building per degree inside-outside temperature differential.

HLP: Heat loss parameter. The total heat loss for the building envelope divided by the floor area to obtain a comparative benchmark.

MVHR: Mechanical Ventilation with Heat Recovery. Functions like a fridge in reverse by extracting heat from exiting air and pre-heating incoming air with this heat.

SIP: Structurally Insulated Panel. Typically used on exterior of housing as an insulation system that also provides structural support in terms of walling, roofing and flooring.

SAP: Standard Assessment Procedure. A method of calculating the amount of energy used and carbon dioxide emitted by a dwelling in terms of regulated emissions: heating, ventilation and lighting.

TRV: Thermostatic Radiator Valve. Controlling mechanism on radiator for heat output.

1. Executive Summary

Introduction

1.1. This final report covers the building performance evaluation (BPE) of Avante at Coxheath undertaken by The Oxford Institute for Sustainable Development: Low Carbon Building research unit between December 2010 and June 2011.

Aim and Objectives

1.2. The aim of the BPE was to learn lessons in hindsight in order to improve future housing design, development and management within Crest leading to improved customer products and services. The objectives consisted of a series of collaborative sub-studies undertaken by the designers, developer and researchers which covered the development process from inception through to early occupancy.

Summary of key findings

1.3. Overall, there have been a number of positive findings in relation to the initial occupancy study of the Avante housing development. These include:

- a better than assumed Standard Assessment Procedure (SAP) value for heat loss and thermal bridging elements
- a slightly better heat loss for the external fabric of a tested home than predicted by SAP
- occupant satisfaction with the housing in relation to customer care, location, the contemporary style, high ceilings, open planning and daylighting.
- occupant satisfaction with overall comfort conditions.

1.4. There have also been a number of findings which highlight particular challenges and opportunities for improving Crest's housing product. These are:

- lack of design development, and understanding of environmental, construction and user consequences in relation to key innovative features: lantern, large windows, external fabric, and Mechanical Ventilation with Heat Recovery (MVHR).
- lack of co-ordination and communication between the developer, design and build teams in relation to the proposed design, installation and commissioning of heating and ventilation systems

- occupant dissatisfaction with storage, some internal specifications and some specific comfort conditions
- poor occupant and staff understanding of MVHR and heating systems which could lead to health risks
- lack of feedback at all stages of the development cycle.

1.5. Key recommendations in response to these findings are set out under three development processes: design, communication, and feedback.

Design recommendations

1.6. Greater iteration and design development of innovative design features are needed prior to the construction stage to ensure that they performed to an optimum level.

1.7. More detailed design consideration of the external fabric and services should be undertaken and properly tested and co-ordinated with suppliers. Improved detailing of the external fabric of the home, and the party wall, will help avoid thermal bridging. This requires a greater understanding of the thermal bridging consequences of detailing decisions in the first place. It is essential to have services strategy fully integrated with the structure and fabric from the outset of design, as this cannot be bolted on afterwards.

1.8. Occupants require greater usability in relation to heating and ventilation controls, as well as a variety of specification improvements as outlined in the Building Use Studies (BUS) survey section of this report.

1.9. Some of the heating and ventilation equipment is unintelligible or inaccessible to the occupants at Avante. Preparation of user guidance at the design stage, rather than after it, would act as a reality check on the usability of designed features.

Communication lessons

1.10. It is imperative to establish a detailed and co-ordinated specification and layout plan for services which works in tandem with the design process. This should go right down to the last control feature and its position in the home.

1.11. More training is needed for installers, site operatives , and customer care staff to ensure that all parties fully understand new technologies being deployed, including how they should be installed, commissioned and maintained.

1.12. Installation and commissioning procedures need to be much more robust, with more detailed requirements provided by the developer and design team in the tender documentation. Action should be taken at tender stage to ensure these requirements are met. This includes identification of competent persons for the procedures and appropriate certification.

1.13. Guidance and handover procedures for occupants need to be clearer and more hands on for heating and ventilation systems to ensure that the occupant is not left confused. This is serious concern in relation to the MVHR, as there are health risks if occupants do not understand how to change the filters or when to change them. Equally, there is confusion about the heating, with the conflict between Thermostatic Radiator Valves (TRVs) and roomstats choices as well as the complex programmer deployed. Occupants need an explanation and demonstration of how to optimally use ventilation and heating controls. Existing occupants need retraining on use of MVHR.

1.14. There is a major opportunity for Crest to develop comprehensive yet bespoke home guidance which can also potentially be used as a marketing tool.

Feedback

1.15. The Crest housing development cycle requires better feedback systems at all stages to ensure continuous improvement. A more detailed developer briefing for the design team is needed, which incorporates documented feedback from lessons learned from previous schemes. Adopting a 'Soft Landings'[1] approach within Crest will assist with this.

1.16. Realistic heating regimes which maximise comfort while minimising resource use require more accurate predictions. This includes more detailed thermal bridging analysis. Performance results should be fed back into the design process to improve the accuracy of the prediction tools (e.g. SAP). This can help to avoid unnecessary cost through unintentionally excessive specification and also highlight potential overheating problems.

1.17. Once on site, a more formal feedback loop is required between the design team and the construction team, to ensure any unavoidable changes are thoroughly reviewed before being agreed and properly documented. The employment of architects only until the end of the design stage left this as a gap in the Avante process. Suppliers and installers also need to be consulted in relation to any proposed changes to ascertain any unforeseen consequences.

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[1] Soft Landings is a process designed to engage the design and construction team with the complete building lifecycle and improve production through continuous feedback and fine tuning. http://www.bsria.co.uk/services/design/soft-landings/

1.18. Consideration should be given to streamlining the BUS questionnaire as part of the general Crest Customer Care process and incorporating it into initial Customer Surveys after the defects liability period.

Further investigation required

1.19. There are a number of findings in this limited study which require further investigation in order to identify causes and solutions for the particular issues identified.

1.20. A further two year monitoring study of a sample of key typologies in Avante would provide physical evidence to corroborate the findings of this initial study in relation to occupant perceptions, building performance and energy use.

2. Project Overview

2.1. This final report covers the Technology Strategy Board: Building Performance Evaluation Initial Occupancy Study of Avante (project no. 16319), which was awarded to Crest Nicholson in November 2010. The Oxford Institute for Sustainable Development: Low Carbon Building research unit was commissioned by Crest Nicholson to undertake the study. This report was submitted to Crest Nicholson on June 17th 2011 and covers studies carried out between December 2010 and June 2011.

2.2. The Avante housing development was initially submitted to the Design for Manufacture competition launched by the Department of Communities and Local Government in 2005. Crest Nicholson was part of the Sixty K consortium which was awarded two sites: one at Renny Lodge (Newport Pagnell) and one at the former Linton hospital site at Coxheath near Maidstone – now known as Avante.

2.3. Both schemes used the TEK SIPS Structurally Insulated Panel (SIP) system for walls and roof but at Avante an innovative roof lantern was added to maximise daylight and control solar gain (the lantern has integral external shading). An outline specification for the project as a whole is described in Appendix vi.

2.4. This study firstly examines the design process and the initial design intentions for Avante as well as the rationale behind any changes made during the development and construction process. The technical study then focuses on one of the plots (Plot 44) and consists of the following elements:

- audit of working drawings compared to houses as built
- SAP 2005 check
- accurate calculation of Y-values[2] and Psi[3] values to check thermal bridging assumptions made in SAP 2005
- co-heating test to establish the actual heat-loss through the external building fabric
- party wall bypass[4] test

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[2] A Y-value is the total heat loss attributed to the linear thermal transmittance divided by the surface area of the thermal envelope considered.

[3] A Psi –value is the *linear* thermal transmittance through a material or combination of materials.

[4] A party wall by-pass is where heat by-passes the insulation provided and creates an unaccounted for additional heat loss via the external envelope or to the adjacent dwelling.

- review of installation and commissioning of the heating and ventilation systems.

The wider social study consists of the following elements:

- interviews/walkthrough with the developer team and design team
- questionnaire survey completed by 42 households
- evaluation of user guidance and handover procedures
- four semi-structured interviews of occupants from different house types (flat, terraced, detached and semi-detached)
- review of control interfaces with occupants

2.5. This summary report draws together the findings and highlights key lessons for Crest Nicholson.

2.6. The documents of the sub-studies associated with the various sections of this interim report are:

- Initial findings report (Section 3 and Appendix i)
- BUS questionnaire report (Section 3 and Appendix v)
- SAP check (Section 4 and Appendix ii)
- Co-heating test report (Section 4 and Appendix iii)
- Installation and commissioning report (Section 5 and Appendix iv)
- Specification for Avante development (Section 2 and Appendix vi)
- Soft Landings (Section 3 and Appendix vii)

3. Design intentions compared to as built

3.1. This section focuses on one of the Avante plots (Plot 44) where the technical tests were carried out. The drawings and specification available for this unit both for the planning submission and construction stage were examined. For earlier aspirations the Sixty K House competition document were scrutinised.

3.2. To record the team's understanding of the building and of the changes made an interview with the design team and a separate walkthrough with Crest Nicholson's team took place in December 2010.

3.3. A number of significant discrepancies have been identified particularly in relation to: external fabric detailing which involved substitution of roofing and cladding materials and alteration to patio doors and windows, changing the layout of bathroom spaces which involved adding an additional door, breaking down the glazing elements of the innovative lantern feature and adding a velux window to it (see photos 1,2,3 below), and altering the number of radiators, boiler position, and layout of MVHR ducting (see figure 1 and 2 below).

There are variety of reasons why this has occurred including lack of co-ordination between suppliers, manufacturers, the design team and site team in relation to positioning, detailing and specification of pre-fabricated elements and services. These are covered in more detail in Appendix i.

Photo 1 - Plot 44 – 1st Floor Bathroom (two doors into it); Photo 2 – Plot 44, Lantern with 4 glass panes and Velux vent window; Photo 3 - Complex leadwork weathering around lantern in apartment block.

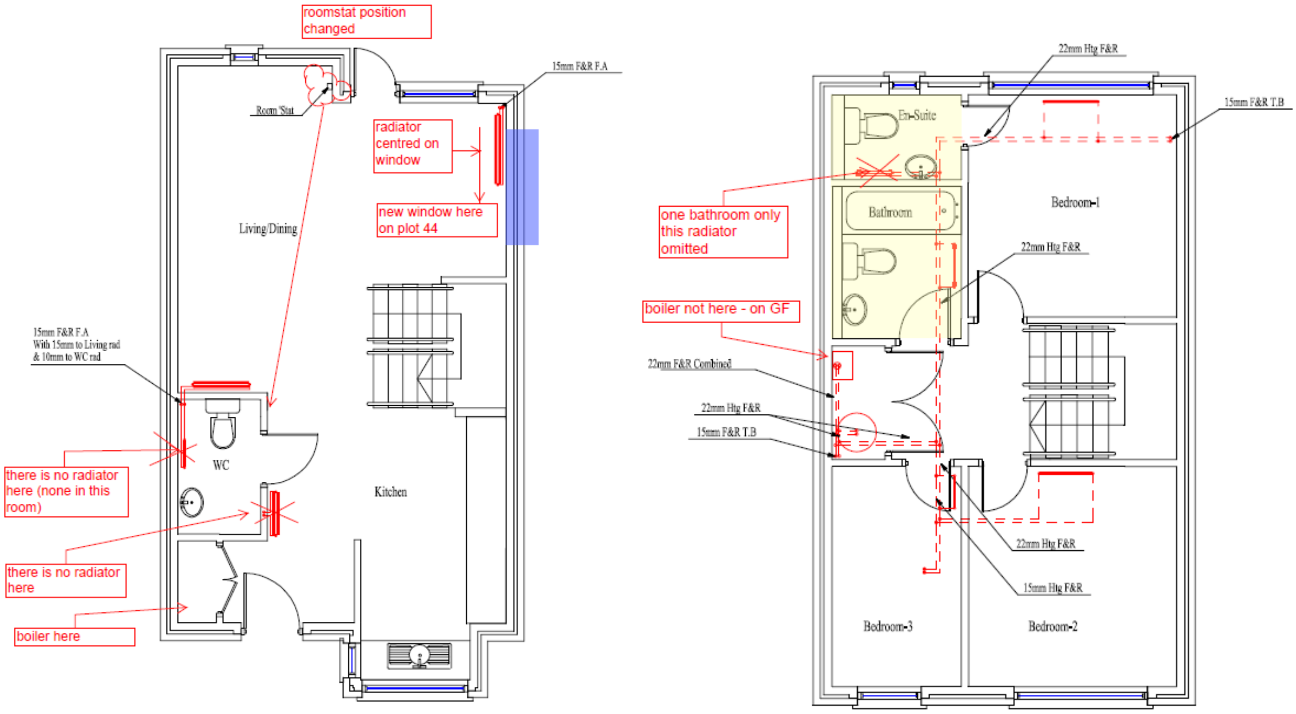

Figure 1 Plot 44 Heating plans with observed changes annotated

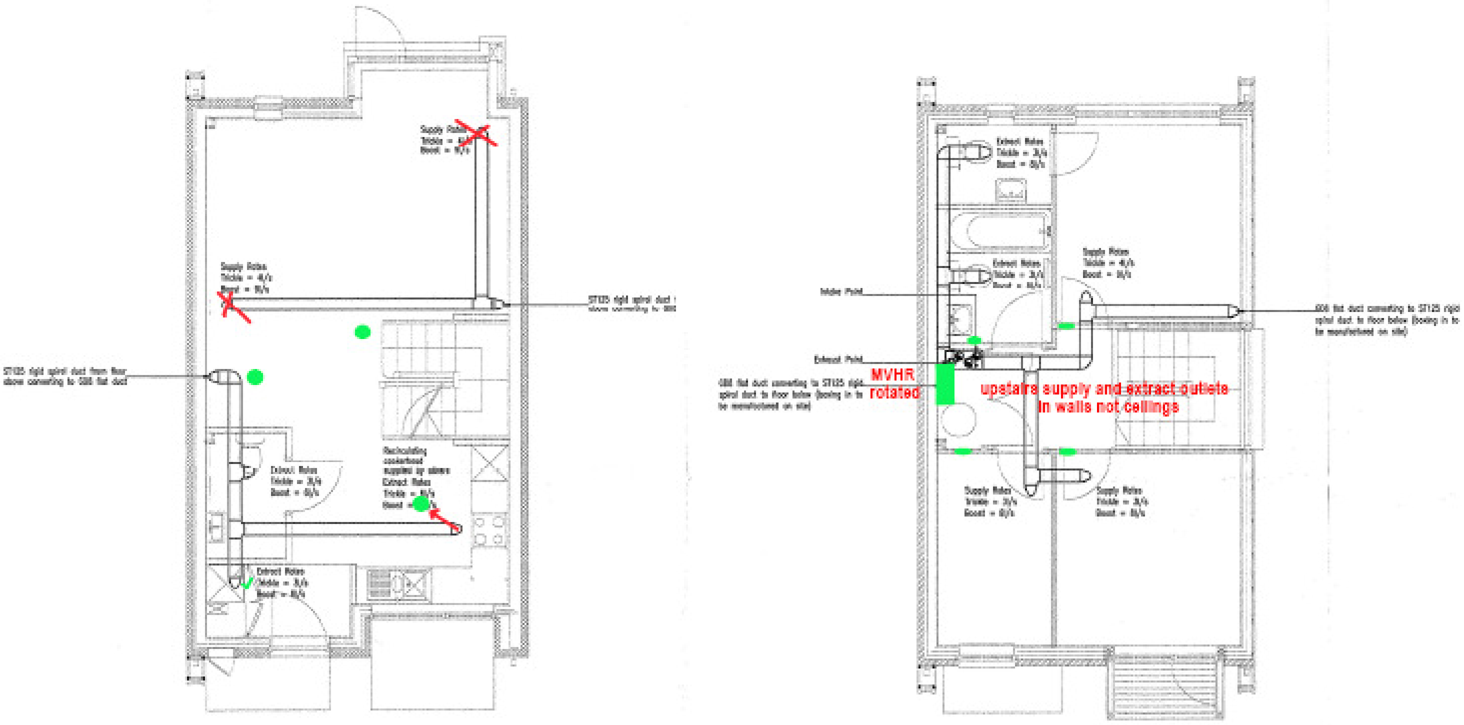

Figure 2 Plot 44 Ventilation plans with observed changes annotated

3.4. A key issue for construction appears to have been the **progression of an innovative design without a full understanding and integration of services** at an earlier enough stage in the design and detailing process to avoid later clashes on site. Complex servicing technologies in housing need to be decided and specified early enough on the design process to allow the spatial and structural strategies to integrate these from the outset.

3.5. **Innovative design elements such as large windows, doors and lanterns need to be refined and road tested for usability** during the design stage, with construction detailing further refined to simplify junctions. – Loading and accessibility for maintenance need to be considered.

3.6. A key issue for organisational learning is the **lack of a clear audit trail for any alterations made to working drawings and drawings once on site.** There are no formalised and complete accounts of specification and drawing changes, making it very difficult for the developer and designers to learn in a structured and logical way why things were changed.

3.7. In some cases, **changes on site have been made without a full awareness of the consequences** (e.g. TRVs next to roomstat, omission of radiators, omission of insulation to pipe work, partial sealing of rainscreen etc.) and suggest that more training is needed on site to communicate the importance of maintaining design intentions when unavoidable changes have to be made which will have an effect on these. Ideally any changes on site should be avoided through thorough design preparation.

3.8. The contractual relationship between the design team, developer and site team needs to be considered in terms of ensuring a greater degree of communication through formalised records, the responsibility for which needs to be clearly agreed beforehand.

3.9. The design of housing is changing rapidly in response to government drivers for major carbon emission reductions in the built environment, and it must be recognised that the Avante development is thoroughly innovative in this respect. This innovation may have exacerbated some of issues highlighted here, but it has also acted as a useful focus on what are often underlying issues in more straightforward housing also, in terms of aiming for continuous improvement of performance.

GENERAL RECOMMENDATIONS:

1. ***Innovative features, usability and construction methods need to be more refined early on, and the details tested and refined in the construction of prototypes to develop best practice, update***

specifications and layouts which are then fixed before a start on site in future developments of the same type – a clear record of the changes and reasons why will help provide the reasoning and understanding of how the building is put together.

2. ***Consider maintenance and cleaning requirements (access) at design stage – e.g. windows need cleaning, drainage hoppers get blocked. Agree the method early so that if a costly solution is chosen, it does not come as a surprise later on.***
3. ***Keep details as simple as possible, standardise to avoid confusion and improve buildability and ease of use.***
4. ***Excessive weight appears to have been a particular issue in relation to several design features. This aspect needs to be carefully considered by the design team.***
5. ***Lessons from the buildability of innovative features and usability of spaces need to be fed back to the next design team and inform future designs – this can be done at inception and briefing when reviewing past experiences as suggested in the Soft Landings Framework[5] stage B2 (see Page 27 in Appendix vii). The original design team should also be informed.***
6. ***The services routing needs to be more considered – a coordinated service plan would help understanding all the connections required and to identify clashes with the building structure.***
7. ***Environmental and performance targets need to be realistic and followed through as a process as in Soft Landings stage B4 (see page 27 in Appendix vii) – a house that needed no heating would have required still greater insulation and air tightness levels as well as a greater attention to detail.***
8. ***Consideration should be given to either a more formal involvement of the design team beyond the working drawing stage, or appointing an equivalent design manager within Crest, to ensure that all changes are properly documented in 'as built' drawings and specifications. This will ensure a continuous and formal in-house learning process.***

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[5] http://www.bsria.co.uk/services/design/soft-landings/

CUSTOMER HANDOVER RECOMMENDATIONS:

1. ***Consider developing more visual diagrammatic guidance for users to refer to once the home induction is over. This needs to be simple, comprehensive and relevant information on how to operate any heating and ventilation of the house to best effect.***

PRE-FABRICATED CONSTRUCTION RECOMMENDATIONS:

1. ***Establish a coordination process to avoid site amendments to prefabricated panels –adopt a 'Lean Construction' approach.***
2. ***Ensure all site detailing is complete and cross-checked prior to going on site with pre-fabricated items.***

DRAWING CO-ORDINATION RECOMMENDATIONS:

1. ***Develop a clear and complete reference system between drawings to avoid confusion on the detailing the designers intend.***
2. ***Establish a clear protocol of responsibilities for specification and coordination between designers and manufacturers to avoid changes of site of prefabricated items.***
3. ***Record changes during construction systematically in drawn format to help communicate the reality of the final product and to allow replication of details that have been altered to work - define whose responsibility this is.***
4. ***Understand how the details represent the needs of the fabric and ensure any changes to the detail maintain them – don't undermine ventilation requirements. Consider amending cladding to retain timber rainscreen condition.***

HEATING SYSTEM RECOMMENDATIONS:

1. ***Check any proposed changes with specialist installer. Explain and record changes to specification and drawing layouts.***
2. ***Ensure the consequences of any changes are understood by site installers – provide additional training if necessary (e.g. uninsulated pipes waste heat).***
3. ***Consider the position of flue outlets to avoid condensation on surfaces.***

VENTILATION SYSTEM RECOMMENDATIONS:

1. ***Ensure co-ordination of ventilation system and other services at an early stage (i.e. when deciding fabric system) and allow adequate space for these within chosen system.***
2. ***Integrate the ventilation system fully with the structure and fabric from the outset, to avoid compromises later on.***
3. ***Check any changes with specialist installer. Explain and record changes to specification and drawings.***
4. ***Ensure site staff understand the consequences of any unavoidable changes (e.g. wall air supply outlets not as efficient as ceiling outlets) and provide additional training as necessary.***
5. ***Consider future maintenance and allow access to duct routes for servicing.***

4. Fabric Performance

4.1. This section reviews the original SAP 2005 assessment for the study plot (see Appendix ii) and then compares the original and corrected SAP 2005 predicted heat loss through the building envelope with the actual heat loss using a co-heating test (see Appendix iii).

4.2. The SAP2005 predicted thermal bridging for the external building envelope (y-value[6]) was double checked by calculating all the two dimensional junctions based on the construction drawings (psi values[7]). The programme used was THERM 5.2.

SAP Check

4.3. The review showed:

- **The y-value calculation (based on drawings) gives a better value (0.048) than the accredited thermal bridging details assumed in the SAP calculation (0.08).**
- Some of the re-calculated U-values also give a better value for the fabric heat loss than the original SAP2005 prediction.
- A larger and more efficient hot water tank had been installed, which further improves the original SAP2005 assessment when recalculated for this change.
- **All of the above gives a reduction on the predicted Target Emission Rate (TER) value of almost 15% on the 2006 building regulations which applied at the time.**
- The original SAP2005 assessment shows a slight risk of overheating if the windows are not fully open for the thermally lightweight SIPS construction at Avante.
- **With a predicted space heating demand of 41 kWh/m^2 year, the SAP2005 shows that the building clearly needs heating**– as a reference Passive Houses that only need MVHR to supply the heating have a space heating demand below 15kWh/m^2 per year.

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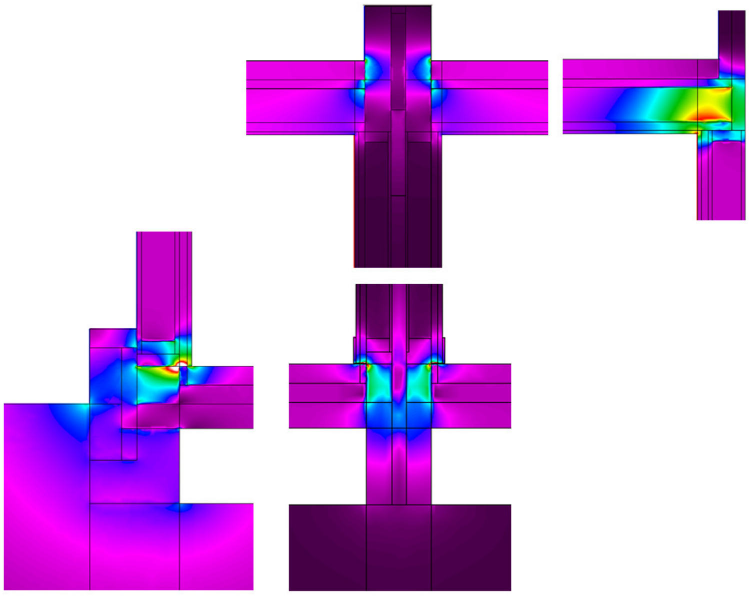
[6] A Y-value is the total heat loss attributed to the linear thermal transmittance divided by the surface area of the thermal envelope considered.

[7] A Psi –value is the *linear* thermal transmittance through a material or combination of materials.

- The calculation of the space heating demand greatly depends on the assumptions taken and the complexity of the calculation – as a comparison we have included in appendix ii a table comparing the assumptions and results for the study plot for the UK's regulatory SAP05 and SAP09 calculations **To meet 2010 part L1A building regulations the design would need to improve its Dwelling Emission Rate (DER) by 10%.**
- Party wall heat losses were not taken into account in SAP 2005. Using SAP 2009 U-value of 0.2W/m^{2}K (unfilled cavity sealed at top), the predicted losses through the party wall would add 8.9 W/K to the fabric heat loss, which represents over 8.4% of the heat losses through the fabric in total. It is not clear what the effect of the timber frame party wall construction with a high timber fraction[8] (averaging 20%) would have on this heat loss value (see 4.22-4.27)
- The geometry of the house is very complex. This made the y-value calculation an arduous task, which would be unaffordable for a small scheme evaluation.
- The greatest contributors to the predicted heat loss in terms of the modelled thermal bridging are ground floor (21%), party wall at ground floor (24%), party wall at parapet (10%) and flat roof parapet (9%) details (Photo 4)



Ground floor Party wall ground and parapet Flat roof parapet

Photo 4 Thermal bridges with greatest contribution to y-value

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[8] Timber frame fraction is the proportion of timber in an insulation layer – typical timber frame would be 15% and for SIPS construction timber frame construction goes down to 5-10%. For this party wall timber frame fraction was calculated from SIPS fabrication drawings.

- Overall, the modelled thermal bridging represents 9% of the fabric heat loss for this dwelling type.

RECOMMENDATIONS:

1. ***The effect of thermal bridges and party walls in relation to heat loss needs to be better communicated to design, clients and construction teams as greater attention to detail is needed both design and construction.***
2. ***Greater efficiency of fabric performance (U-values, thermal bridges and air tightness) is needed to push towards genuinely low carbon homes.***
3. ***SAP gives an indication of heating demand and of ventilation needs to avoid overheating which can inform the design and avoid false expectations.***
4. ***It is important to properly calculate thermal bridging and not assume accredited details in SAP as the accredited details are not an accurate representation and may overestimate the thermal bridging involved leading to unnecessary expense in meeting the building regulations.***
5. ***Psi value and y-value calculations need to be better understood and a simpler methodology and guidance developed to allow smaller schemes to benefit from improving these values.***
6. ***There needs to be an understanding of the assumptions made by the SAP assessor by both the designer and the client's technical team in order for them to advise the assessor whether they reflect or not the actual construction of the building.***
7. ***Changes from the design stage should inform the as built SAP calculation – using actual U-values of products and efficiencies of products installed.***

Co-heating test process

4.4. Co-heating testing aims to determine actual as-built building heat loss through the fabric and by air infiltration (see Appendix iii for full report). The main output is a measurement of the actual Heat Loss Coefficient (HLC) for the building[9]. The

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[9] HLC (units of W/K) is defined as the heat loss from the building per degree inside-outside temperature differential.

measured heat loss can then be compared with the predicted heat loss as calculated in SAP2005.

4.5. Co-heating tests are usually carried out in a completed but unoccupied house over a period of at least three weeks between November and March. Outside this period it is unlikely that the required temperature differential of 15℃ will be achieved. The house is heated by electric fan heaters to bring it up to 25℃, using large fans to ensure even heat distribution. Temperature and relative humidity are recorded at ten minute intervals in the rooms using wireless sensors communicating with a central datalogger.

4.6. Air permeability (blower door) tests are carried out before and after the test, using both depressurisation and pressurisation to 50Pa to establish an average figure for air leakage and hence air infiltration heat loss.

4.7. Tracer gas (carbon dioxide) decay tests are also run every day during co-heating to measure the actual infiltration in this period. Wireless CO_2 sensors monitor CO_2 concentration (parts per million, ppm) both upstairs and downstairs throughout the test period.

4.8. All electrical consumption by heaters, fans and sensors is measured by pulse output meters connected to each extension lead used and recorded at ten minute intervals by pulse transmitters communicating with the central datalogger.

4.9. A weather station mounted at roof level records outside temperature, relative humidity, solar radiation on the vertical plane (South-facing), wind speed and direction.

4.10. Data is averaged over each day, and corrected for solar radiation and wind influences.

4.11. Heat flux sensors are placed on party walls to measure the heat flow across the wall. Next door houses are kept at 25℃ also to ensure zero heat loss (theoretically).

Photo 5 Co-heating test equipment in Bedroom 2

Photo 6 Weather station at top of roof lantern

Air permeability results

4.12. Air permeability results were obtained from two air pressure tests. **The averaged results of 5.82 m^3/h/m^2 were higher than the predicted SAP values of 5 m^3/h/m^2.**

4.13. Infra-red imaging carried out during the air pressure testing located **air leakage around service penetrations in kitchen and bathroom, Velux windows, some glazed panels, and skirting boards in all rooms.**

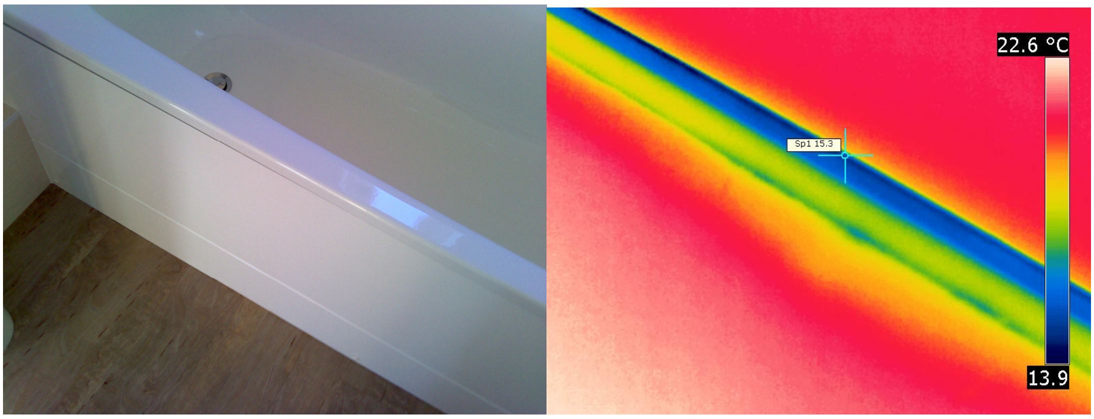

Photo 7 Air leakage from behind bath panel attributed to service penetrations

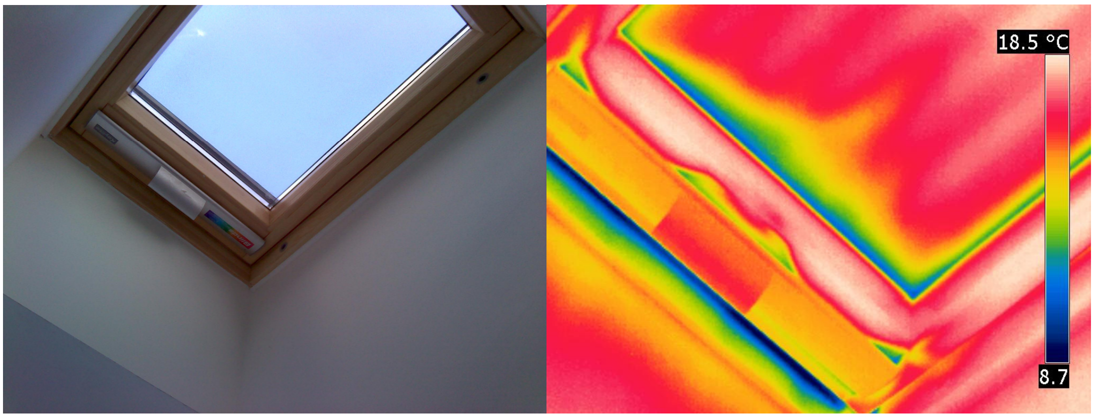

Photo 8 Air leakage around Velux showing poor seal between frame and ceiling and glazing

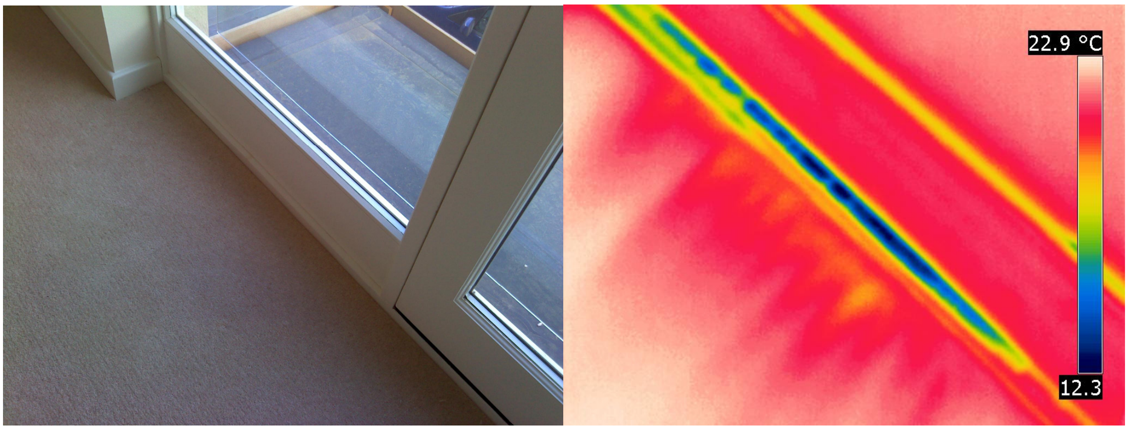

Photo 9 Air leakage under Bedroom 2 glazed panel

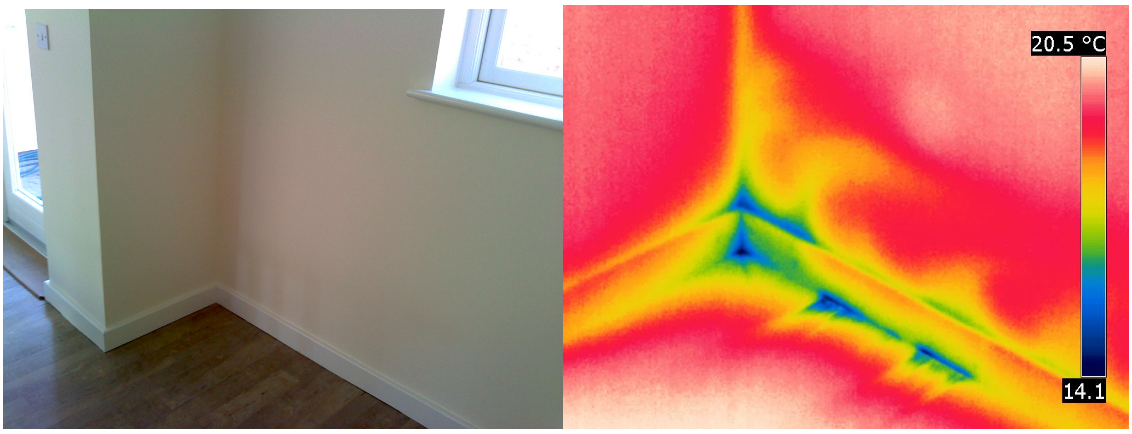

Photo 10 Air leakage around living room skirting board from junctions between floor and wall

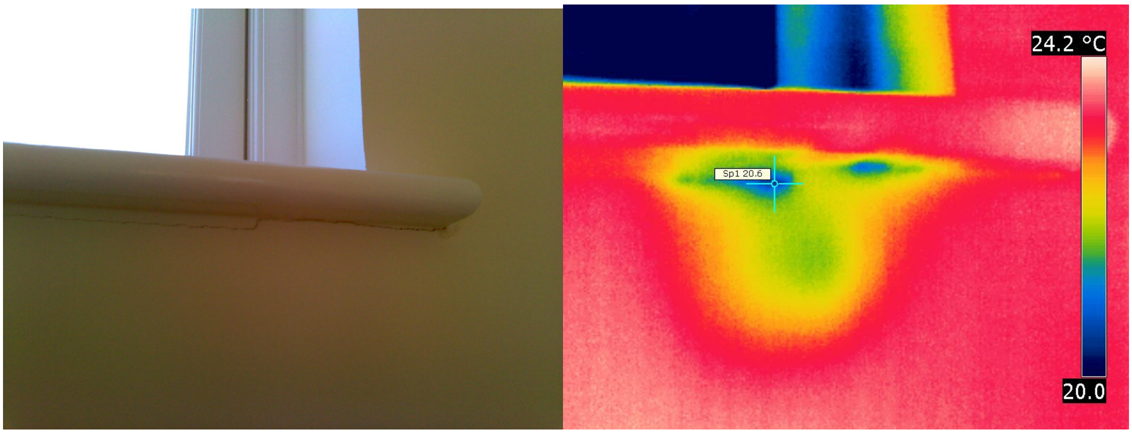

Photo 11 Air infiltration through crack beneath window sill at joint, Bedroom 3

Co-heating test results

4.14. Daily average values for **heating power consumption**, corrected for solar and wind influences, were plotted against the **inside-outside temperature difference.**

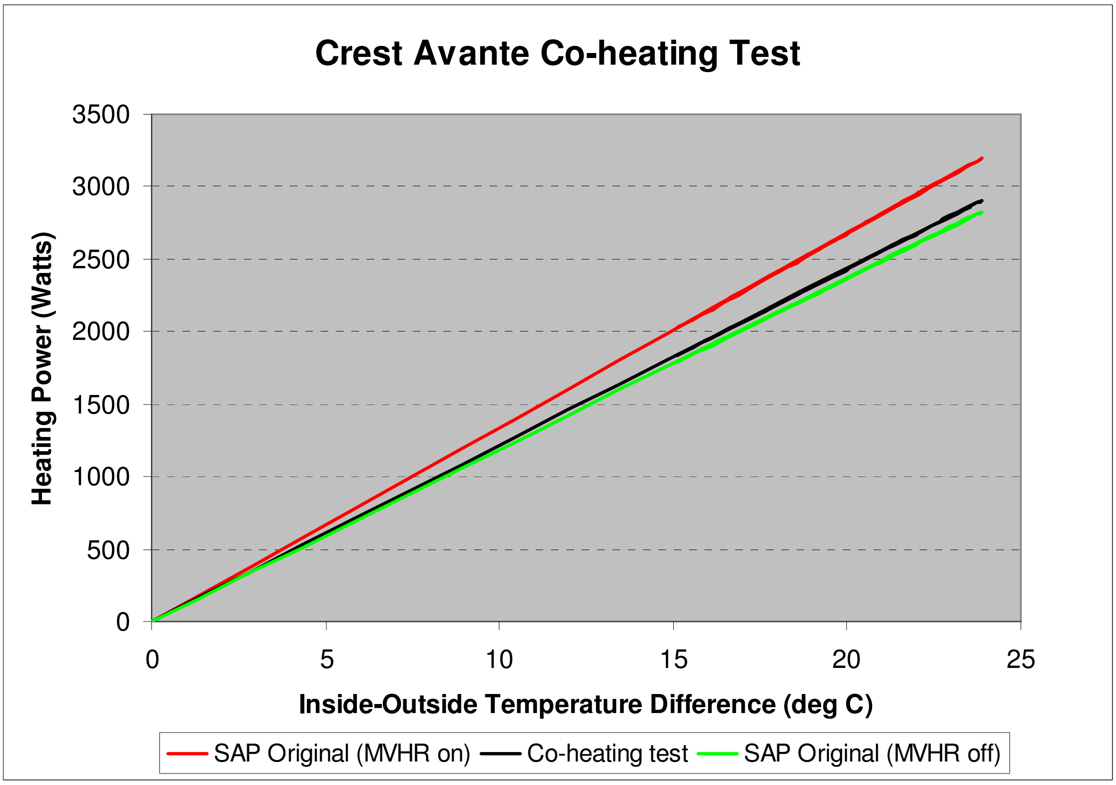

Table 1: Heat loss co-efficient for Plot 44

4.15. The top red line of the graph represents the original SAP2005 prediction trend with the MVHR assumed to be switched on and the second black line shows the actual tested

Heat Loss Coefficient (HLC) trend. The third green line represents the original SAP 2005 trend when the MVHR assumption is taken out. The graph shows:

4.16. Actual HLC = 121.64W/K
Predicted HLC (original SAP 2005 with MVHR on) = 133.96W/K
Predicted HLC (original SAP 2005 with MVHR off) = 118.45 W/K

4.17. **This shows an improvement of 9% on the predicted heat loss flowing through the fabric using the original SAP2005 assumption of the MVHR switched on, but a slight underperformance by 2.7% when the MVHR assumption is taken out.**

4.18. When this heat loss is divided by the floor area of 86.46m^2 we obtain what is called a Heat Loss Parameter (HLP) which gives a benchmark per square metre which can be used for comparative purposes with other dwellings:

4.19. Actual HLP = 1.41W/m^{2}K
Predicted HLP (original SAP2005 with MVHR on) = 1.55W/m^{2}K
Predicted HLP (original SAP2005 with MVHR off) = 1.37W/m^{2}K

Comparison with SAP

4.20. The figures from the co-heating test are now compared with the original SAP 2005 calculation figures and the corrected figures obtained from the SAP check using a y-value of 0.048.

Table 2: Heat Loss Coefficient W/K				
	Ventilation W/K	**Total Fabric W/K**	**Thermal Bridging W/K**	**Total W/K**
Original SAP2005 MVHR on	32.22	101.74	17.84	133.96
SAP check y=0.048 MVHR off	16.7	96.95	10.11	113.65
Co-heating test	24.18	97.46	10.11	121.64

4.21. **As before, the co-heating test result for heat loss is better than the original SAP 2005 prediction (9%) but slightly worse by 7% than the corrected SAP check with the MVHR now turned off. This latter finding is partly explained by the higher air infiltration rate measured during the test.**

4.22. The ventilation loss calculated for the co-heating test is approximately 25% lower than the figure used for the original SAP2005. This is because SAP2005 assumes an ‘effective infiltration rate’ that takes into account the effect of the MVHR system and its heat exchanger efficiency. This system was completely sealed and turned off during the co-heating test, and the measured value of air infiltration was used. The different ventilation rates largely account for the difference between the co-heating test heat loss total and the original SAP2005 predicted heat loss total.

4.23. **Overall, the actual heat-loss co-efficient for the external fabric compares well with the original SAP 2005 values**. As such the home has performed slightly better than expected. This is despite the poor performance of the party wall (which did not need to be taking into account for SAP2005 or the building regulations in operation at the time Avante was designed), and **suggests that the SAP modelling is overly conservative in relation to the rest of the external fabric.**

Party wall bypass testing process

4.24. The house chosen to be tested was an end-of-terrace property, providing one party wall to consider. In SAP2005, the party wall is assumed to have zero heat loss as the next door house is presumed to be at the same temperature. However, in reality this may not be the case for a variety of reasons and testing is required to establish if there is any unexpected heat loss from the party wall. It should be remembered that Avante was not designed to have a party wall with zero heat loss because at that time there was no requirement to, and the building regulations simply assumed that party walls were zero heat loss by virtue of being an internal wall. Under current building regulations (2010, that the heat loss from a party wall is taken into account in SAP2009.

4.25. An array of four heat flux sensors (HFS) was installed on the living room party wall to record heat flux every ten minutes throughout the co-heating test. Not knowing the precise construction of the party wall, which is of framed construction rather than SIPs, this regular array was considered the best arrangement at the time.

Photo 12 Heat flux sensors on living room party wall

4.26. **The measured rate of average heat loss of 181.24 Watts for the whole party wall is much bigger than expected and was found to be approximately 7.9% of the total heat loss from the building.**

4.27. It is thought that the cavity between the house walls is not properly filled with insulation and sealed, leading to air movement and heat loss from the cavity to the outside. This view is corroborated by the thermal imaging:

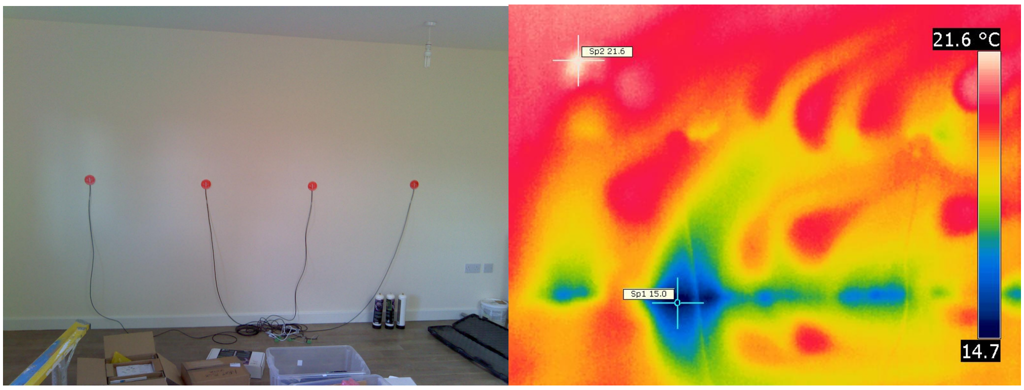

Photo 13 Living room party wall heat flux sensors and heat loss

4.28. Note cold bridging (blue areas) in a line approximately mid-way between the skirting board and the sensors (600mm from floor). This wall is subject to some solar gain from the lantern in the stairwell opposite, but this cannot explain the temperature variation witnessed. **The party wall was also photographed from the outside (rear elevation) which revealed significant thermal bridging through the parapet detailing**. Examination of the drawn details also show potential thermal bridging at the foundation detail for the party wall, although this has still to be confirmed.

Photo 14 Outside rear elevation – party wall junction showing heat loss at parapet.

4.29. Several weeks following this testing, it was discovered via drawings obtained from SIPS manufacturer that **the party wall consisted of unforeseen complex timber joist supports within the SIPS party wall panel which would account for further significant thermal bridging**. When the house next door is unoccupied and unheated, the party wall effectively becomes an external wall and so this thermal bridging is important.

RECOMMENDATIONS:

1. ***Higher than expected air permeability (5.82m^3/h/m^2 compared with the target value of 5m^3/m^2/h) should be reduced by close attention to build quality of key junctions, skirtings and service penetrations.***
2. ***The party wall should be investigated further because heat flux measurements indicate much greater than predicted heat flows. It is thought that the cavity between the two framed walls is allowing air flow to the parapet detail (which in itself provides a thermal bridge) or even directly to outside. Further infra-red, heat flux testing, and inspection would yield valuable lessons for future houses.***
3. ***SAP as a tool needs to be improved to provide more accurate modelling of fabric heat losses, as it can be overly conservative in its default values.***
4. ***Further investigation is needed to assess the effective infiltration rate and subsequent heat loss from the home when MVHR is switched on and to compare this with assumed SAP values.***

5. Installation and Commissioning

5.1. This section covers the review of the compliance and effectiveness of the commissioning processes for the **heating, domestic hot water and ventilation installations** (see Appendix iv). The review included interviews and walkthroughs with the installation engineers, inspections of the installed systems (including measurement of the ventilation system flow rates), handover processes and set-up of controls.

5.2. A document review was undertaken to understand where variances from design stage to installation stage had occurred and to determine whether manufacturers' installation guidelines had been followed. The following documents were considered:

- Manufacturers' recommended installation and commissioning procedures
- Installers commissioning reports where available
- Heating equipment layouts
- Ventilation equipment layouts

Ventilation results

5.3. Site measurements were taken of the ventilation flow rates to determine correct system balancing and whether the measured flow rates met the design values for the Greenwood HRV 1 unit and MVHR system.

Photo 15 Greenwood HRV 1 unit with flexible ducting in airing cupboard

5.4. A summary of the results for the whole-dwelling are:

- Supply air ventilation rate is sufficient for meeting the requirements of the Building Regulations, **although in boost mode, the total rate of 17.0 $l.s^{-1}$ is lower than specified by the system designer (Greenwood Air management ltd).**
- Extract ventilation rate is slightly below the minimum low rate of 15.8 $l.s^{-1}$ in trickle mode for meeting Building Regulations. **However, the minimum high rate (boost mode) of 20.3 $l.s^{-1}$ is approximately 40% below the minimum flow rate required to satisfy Part F.**

5.5. There are two main issues relating to the underperformance of the ventilation system.

- **The most critical issue is the amount of installed flexible ductwork.** Flexible ductwork has higher air resistance properties compared to rigid duct and sagging further contributes to reduction in flow performance. Flexible ductwork should be kept to an absolute minimum, preferably eliminated. By using rigid ductwork, it is probable that the dwelling would be compliant with the 'Normal/minimum low rate' values given in Approved Document F (2006)

- The second issue relates to **commissioning.** The systems have been fully commissioned by the installation engineer following guidance from the manufacturer. However, **problems were found with the set-up configuration with the installer's air flow measurement instrument**, which resulted in higher readings to the order of 1.5 to 2 times greater than actual. Hence, the installation engineer has inadvertently reduced the supply and extract fan speeds and adjusted terminal valves such that the values, as displayed on the commissioning air flow instrument, matches the manufacturer's notional design values. Consequently, the design flow rates have not been met.

5.6. Air gaps between the bottom of the doors and flooring, in the main, are sufficient. The exception being the bathroom to bedroom door which has no undercut. Cross flow ventilation is not possible without having a 10mm undercut beneath doors.

5.7. The manual boost switch has been located at a high level in the airing cupboard adjacent to the fan unit (see photo 15). **This will be inaccessible to some occupants and, designers should note that the location is non-compliant with the Building Regulations, Part M (access and use).** Boost switches should be located adjacent to bathrooms and/or kitchen areas to give a level of user control, e.g. during bathing and cooking times.

5.8. Commissioning documents for the ventilation installation have been lost for this plot. **Every attempt should be made to obtain this document, or preferably recreated following re-commissioning.**

Heating and hot water results

5.9. In general, plant associated with heating and hot water would appear to follow manufacturer's requirements. The following highlights the departures noted during the inspections:

- The boiler installation (Ideal ICOS 12 HE unit) has been sited in an alternative location to that shown on the drawings. The revised installation is at the front of the dwelling, which has resulted in the flue terminating adjacent to the front door under the porch roof. **The siting of a condensing flue terminal in this location may cause plume nuisance and premature and non-uniform degrading of the cedar panels above the flue.**

- **Drainage pipework connecting pressure relief from megaflow hot water cylinder and ventilation system condensate has inadequate fall,** which may result in water stagnating in horizontal sections.

- Commissioning processes for heating and hot water systems have tended to follow the manufacturer's guidance and industry's 'Benchmark' scheme. Only the boiler Benchmark commissioning checklist is available. **A completed Benchmark document for the hot water installation was not made available** during this review.

- Commissioning for efficient operation and control relies upon manufacturers default settings in the various control elements. Effective communication of the use of these elements will be essential for ensuring end users are able to tailor to suit their comfort needs in the most efficient way.

RECOMMENDATIONS:

1. ***Flexible ductwork should be kept to an absolute minimum, preferably eliminated.***
2. ***Ensure installer has been fully trained and carry out sample testing of air-flow rates during commissioning stage.***
3. ***Maintain adequate undercuts to ALL doors for cross-ventilation.***
4. ***Locate boost switches where they can be easily reached adjacent to bathrooms and kitchen areas.***
5. ***Locate boiler flue away from protrusions which can be compromised.***
6. ***Maintain adequate falls to all drainage.***
7. ***Provide effective guidance to user on the default settings and how to optimise heating and ventilation in relation to these.***
8. ***Ensure that competent persons are identified for carrying out installation and commissioning with suitable certification.***
9. ***Ensure commissioning documents are available for all installed systems, i.e.***

    - ***heating***
    - ***hot water***
    - ***ventilation***

6. Handover and Guidance

6.1. This section covers the review of the documentation homeowners receive from Crest Nicholson before they move in (Avante Master Manual), when they move in (Home User Guide box) and during the personalised handover process of their home. The Home Demonstration tour for a detached house was witnessed and evaluated on 15th February 2011. The purpose of the review is to understand the information that the home owners receive and how it is presented in order to provide guidance on how it can be improved.

6.2. Generally, Crest documents and activities relating to the handover of the houses give a good, orderly impression and they give confidence to the customers about the home they are buying.

6.3. During the home demonstration, Crest staff were very friendly and charismatic and it was apparent that they were developing a relationship of trust with the new home owner.

The Master Manual

6.4. The information is very informative in this manual regarding legal matters of the buying process. However, it would benefit from:

- being more specific to the scheme for greater clarity,
- providing diagrams and pointing out all unusual features of the scheme (e.g. construction, ventilation),
- ensuring that only relevant items are covered in checklists listed.

The Home User Guidance Box

6.5. This box provided various certificates and manuals needed for various fittings and appliances but, some of these manuals are very lengthy, highly technical and not particularly user friendly. It would benefit from:

- explaining in simple visual terms using diagrams to illustrate and locate:
  a. what the construction is,
  b. what the heating and ventilation strategy is,
  c. where the emergency cut off points are for water, gas and electricity,

d. where controls are provided,
e. how to operate all appliances for best efficiency (without relying on defaults).

The Home Demonstration Tour

6.6. This tour highlighted that **there is a significant misconception in the handover process about what the MVHR actually does**. Ventilation was not mentioned once (and as there are no trickle vents this is the occupants' only means of getting background ventilation) and the Home Demonstrators thought the MVHR would "balance" the heat of the house, when in fact it cannot do this on its own, as supplementary heating is needed.

6.7. The frequency for changing the MVHR filters was related to fixed timescales rather than to the actual accumulation of dirt in the filters. **There was no demonstration of how to get into unit for cleaning the heat exchanger filter** (the manual is not clear either on this one).

6.8. The fact that the roomstat controls the temperature setting and the TRVs are subservient to it is not fully understood by Home Demonstrators. This can be confusing for customers trying to understand how to optimise the heating system. The tour also did not include an explanation of how to set the programmer, which can seem very complicated for non-technical or elderly people.

6.9. The customer tried out windows and doors and bathroom fittings but **they had no hands on experience of the controls** for the ventilation system, the MVHR filters, the heating controls or programmer, the boiler on/off procedure, or the electricity panel.

RECOMMENDATIONS:

1. ***The Home User Guidance should give a more diagrammatic visual explanation of the house (specific to each property type) including the construction, service locations and emergency points and environmental features of the property[10]–***
2. ***By giving this additional guidance at an early stage (e.g. included in the Master Manual), it should be possible to create opportunities at the***

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[10] The format of such a leaflet can be similar the Low Carbon Home Guide but specific to Avante and the plot and house type in question.

Home Demonstration stage for the user to interact with the equipment and to ask questions on how it may actually work to best effect.

3. ***Simplify the information in the physical Home User Guidance but give sources of further information which are web-based using website links.***
4. ***Training of the handover staff is needed in more detail so that they fully understand the installed systems and the interaction needed to be carried out by the user. Staff are very much trusted by the customers who rely on them as a first source of useful and accurate information.***

7. Building Use Studies Questionnaire

7.1. This section covers the results of the BUS Questionnaire survey that was carried out at Avante in late January/early February 2011 (see Appendix V). This was a large sample of 135 houses from which 42 responses were received, giving a high response rate (31%). The purpose of the survey is to understand how well the dwellings meet the occupants' needs, the perceived level of comfort within the dwellings and the degree of control they feel over the environmental features of the home. The survey also collects comments made by the respondents under each of the categories.

7.2. Positive aspects of the design are **the location, contemporary look, open plan ground floor, good toilet and daylight provision.**

7.3. Items that require further development are the kitchen layout, its size and storage; **the lack of storage space**; durability of finishes; entrance sequence, door quality and draught exclusion; heating provision; shading provision, heating controls, cooling/ventilation and lighting (mainly daylight); artificial lighting quality and quality of light fittings.

7.4. Generally the overall comfort condition, temperatures, noise and lighting seem satisfactory. However, **the development demonstrates a high level of 'forgiveness' in the design, with people willing to put up with less than satisfactory environmental conditions because of the enjoyment of the design overall**, rather than an absence of issues. Under each category, the detail variables show room for improvement (**temperatures too hot in summer and cold in winter; air dry in both summer and winter;** variation on the perception of draughts).

Some of the design changes highlighted in the Initials Findings report (see Appendix i) e.g. omission of radiators, may have affected this outcome. This reinforces the need for understanding the consequences of any omissions/changes to the design intentions.

7.5. **Noise was reported as troublesome** between neighbours, between rooms within the dwelling and from outside. The acoustic performance of party walls and internal partitions need testing and reviewing to ensure as constructed they perform as expected.

7.6. **There are a number of complex user issues highlighted in relation to the MVHR system*,*** despite ventilation levels appearing to be satisfactory overall; users report opening windows for ventilation and getting frustrated when they cannot get adequate cool air or hot air from the MVHR system. They don't seem to understand the ventilation system or what it does (they expect it to heat the house). A ventilation system that is not performing as it should or not being maintained properly (e.g. cleaning and changing filters) may cause further air quality problems. In addition, the air quality is reported as being slightly too dry which may be a consequence of the MVHR system. The provision of sufficient ventilation is paramount to avoiding condensation and mould growth. Overly dry conditions, however, can cause other user health problems related to dry sinuses, dry skin, breathing difficulties and excessive static electricity. These conditions can also affect the building fabric, introducing excessive cracking at the joints.

RECOMMENDATIONS:

There are a number of strategic during the execution of the housing development process where interventions need to be made in order to avoid the problems identified in the BUS survey re-occurring in the future. These can be summarised in relation to the RIBA plan of work and the 'Soft Landings' strategy as follows:

1. ***SL Stage 1 (Inception and Briefing): provide clearer guidance to design team on user requirements for kitchen layout, storage, daylight control, usability and ease of access for all control points for ventilation, lighting and heating, and maintenance.***
2. ***SL Stage 2 (*****Design Development and Review)**:
    - i. ***Review lobby-less entrance to living space and open plan design with lantern to avoid creating draughts.***
    - ii. ***Improve specification for draught proofing of doors.***
    - iii. ***Review kitchen layout, acoustic performance, durability of finishes and lighting specifications.***
    - iv. ***Consider provision of more thermal mass to prevent overheating in summer.***
    - v. ***Prepare user guidance in tandem with design drawings and specification to help identify any potential issues with proposals.***
    - vi. ***Double check usability and access for all user interfaces e.g. windows, MVHR controls and maintenance of these elements.***

3. ***SL Stage 2 – D3 (Tender Documentation and Action):***
    i. ***Review tender documentation to ensure that robust installation and commissioning procedures are requested for ventilation and heating systems, especially for MVHR system and settings.***
    ii. ***Evaluate responses from sub-contractors, specialists and installers and add additional requirements where necessary.***
4. ***Construction: ensure that any proposed changes on site are properly documented and thoroughly reviewed with design team and specialists in terms of consequential effects on standards and usability, particularly in relation to changes to heating and ventilation systems.***
5. ***SL Stage 3 (Pre-handover): develop greater dialogue between design team, suppliers and developer to ensure that installation, commissioning processes and user guidance is thoroughly co-ordinated, particularly in relation to MVHR systems.***
6. ***SL Stage 4 (Initial Aftercare): review user guidance and handover procedure in relation to MVHR system, provide more training to handover staff on technical aspects or arrange for installer to be present at handover. This is a cause of a major amount of user misunderstanding at the moment.***

8. Occupant interviews

8.1. This section covers the review of the interviews carried out with four sets of occupants from Crest Nicholson's Avante housing development during February 2011. Each set of occupants were related to a different house type (four bedroom detached, two bedroom flat in an apartment block, two bedroom end terrace and two bedroom flat over garage) The purpose of the interview is to find out their level of satisfaction with the handover process and the appeal of the house, to check how they feel about the comfort and control of the different systems in their home (heating and hot water, ventilation, daylight and lighting, noise) and what they think about the space standards and their flexibility. The walkthroughs go through specific items in each of the rooms of the house looking at the best and worst for each space.

8.2. Customers seem **happy with handover and customer care received** even when they have had problems with some items and a solution might have entailed important changes such as the change of windows or doors.

8.3. Interviews in different house types have helped to find out more specific lessons per house type which could also inform the BUS questionnaire results. For instance, the space standards are different in the different house types and the **occupants of the detached dwelling felt the main bedroom was a bit tight** once they had added the wardrobes. The occupants of the other dwellings (all two bedroom properties) commented on the good size of the bedrooms. The BUS questionnaire report also collected this comment[11] and the response towards storage provision was varied.

8.4. Occupants were **positive** about:

- the **amount of daylight** in the homes - a good unanimous point in all dwellings – (*"absolutely fantastic");*
- **location of the development** ("*The location is definitely key.")* in a village with amenities and in the countryside;
- the **open plan ground floor layout** divided by the stairs in the end of terrace two bedroom dwelling which meant the space could still be defined by separate uses. The open plan living/dining/kitchen in the apartments and detached house was also liked sometimes with a small compromise on noise;
- **high ceilings** upstairs in the end of terrace dwelling;

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[11] See section 3 of BUS questionnaire report

- the **lantern area providing good views and a sense of uniqueness** – there were however comments about difficulties in reaching for cleaning and some movement cracks were apparent in the two bedroom dwelling (photos 16 and 17 below);
- kitchens' layout - however, some would like more storage or not have to trade storage for a dishwasher space;
- amount of sockets, TV and aerial points- however, these are not always located where the occupant expected them and some of them had to run cables under the floor. Others found that the rooms could only be organised in one way for the sockets to be practical.

Photo 16 and 17 (left) &1b (centre) cracks at lantern base.

Photo 18: rooflight in lantern

8.5. Occupants were **less favourable** about:

- **lack of visitor parking** in the front area apartments;
- **having leaky doors** that flooded the rooms when it rained in the apartment dwelling (doors had been changed and sealed for noise) and a leaky kitchen window in the two bedroom house;
- a very **dark corridor** (poor artificial lighting) –see photo 19- with a dead space at the end of the corridor (bathroom door opens towards it blocking the light) in the apartment above the garages;
- the washing machine cupboard (in the apartment above the garages) which is too small for the washing machine (see figure 1e)– this is the cause of great concern as **vibrations from the washing machine carry through the apartment** and the occupant now sets it on a timer so that they are not in when the machine is in use.;
- **artificial light fittings (*"look cheap"*)** – most of them have changed the light fittings and not always for energy efficient lights as there is greater choice of cheaper non energy efficient fittings; some also found difficult to find the right lamps for the energy efficient downlights;

- **having to open skylights with a pole as it is a difficult task** requiring great strength (photos 21 and 22);

Photo 19 (left) dark corridor, Photo 20 (centre) small washing machine cupboard, Photos 21 and 22 (right) kitchen skylight needs opens and closes with a pole.

- **full height windows in the bedrooms were not always liked** as some occupants felt there was a lack of privacy when the bed is visible from the street and they had fitted some bespoke blinds that run from the floor up;
- **condensation on the garden large French doors metal thresholds** in the detached dwelling (see photo 23 below) from which they have to wipe the water collected on thresholds everyday;
- **lack of electricity and power in the garage** of the detached dwelling *("very angry and disappointed about that")*.

Photo 23 (left) condensed water collects in aluminium door cill, Photo 24 (right) damaged MVHR display

8.6. **All occupants ventilate their homes manually and report the houses getting hot in summer** otherwise. In the apartment, the occupant opens the front door to the access corridor and a window on this corridor (which faces north) to create a cross flow of fresh air. The occupants of the two bedroom house keep windows open during the day when they are in, especially in summer; however, their **rooflight above the lantern (photo 18) would not close due to movement when we visited and they kept it closed and use windows instead to ventilate the stairwell which is less effective**. In the apartment above the garages, the occupant reported that food does not last in the cupboards and has an additional fridge in the garage for summer use.

None of the occupants mentioned switching the MVHR to summer (bypass) mode so the ventilation unit would still be recovering heat in summer– air quality was reported as still in the BUS questionnaire survey.

8.7. Occupants seem to have **little understanding of the detailed functioning of the MVHR units. They do not consider MVHR as part of their ventilation system and do not interact with it easily –** in one of the dwellings the occupant complained about cold air from the vent in the dining area and on inspection the boost switch was on without the occupant being aware of what it meant. The display was also fading and out of place (photo 24 above) showing various symbols which the occupant did not understand.

8.8. **Customers do not seem aware of the maintenance requirement for the MVHR filters** – the MVHR unit displays a regulated warning symbol to indicate that the heat exchanger filter should be cleaned but the occupant did not know this was necessary nor how to carry out the task. Most occupants reported cleaning the filters that slide out of the front of the unit, but **in one case the filters were clearly inaccessible and difficult to reach.** In another case we showed the occupants during the walkthrough where they were located and how to take them out and found them so clogged up that the customer cleaned them during our visit (see photo 25).

Photo 25 MVHR filter as found (left) and after cleaning (right)

8.9. **Access to the MHVR units is quite difficult in some layouts** (see narrow cupboard in photo 26). The display panels are not easy to see and the maintenance of the filters is difficult or not possible, in some cases, due to the unit being placed out of reach or clashes with door frames (photo 27). **The occupants also tend to fill the cupboards with shelves and use them as storage (photos 26 and 28) which makes access to the boost switch that has been located normally on the rear wall difficult**. It would be better to position such a switch in a location that allows easier access and is connected to the need for boosting the air flow (e.g. in the kitchen as suggested in the commissioning report).

Photo 26 (left) narrow inaccessible cupboard with MVHR, photo 27 (centre) door frame clashes with filter, Photo 28 (right) MVHR cupboard as storage

8.10. Some **cold spots were reported in most of the homes**: in the two bedroom apartment, the space by the large French doors felt chilly, the occupant felt the location of the living room radiator should be closer to the external wall. In the apartment above the garages, the occupant reported that the main bedroom and downstairs by the entrance door get cold very quickly. The downstairs toilet without a radiator or towel rail was reported as a cold space in the detached house.

8.11. **Some noise was reported** between rooms in the apartment above the garages and between dwellings in the end of terrace house. Noise carries throughout the house in the detached house with the open well above the entrance hallway. Noise from outside was not perceived as a problem except in the apartment above the garage where the occupant felt it sounded *"like an amphitheatre"* when children played outside. The apartment on the main road had had sound proofing retrofitted on the external doors retrofitted by Crest Nicholson which had eliminated the problem.

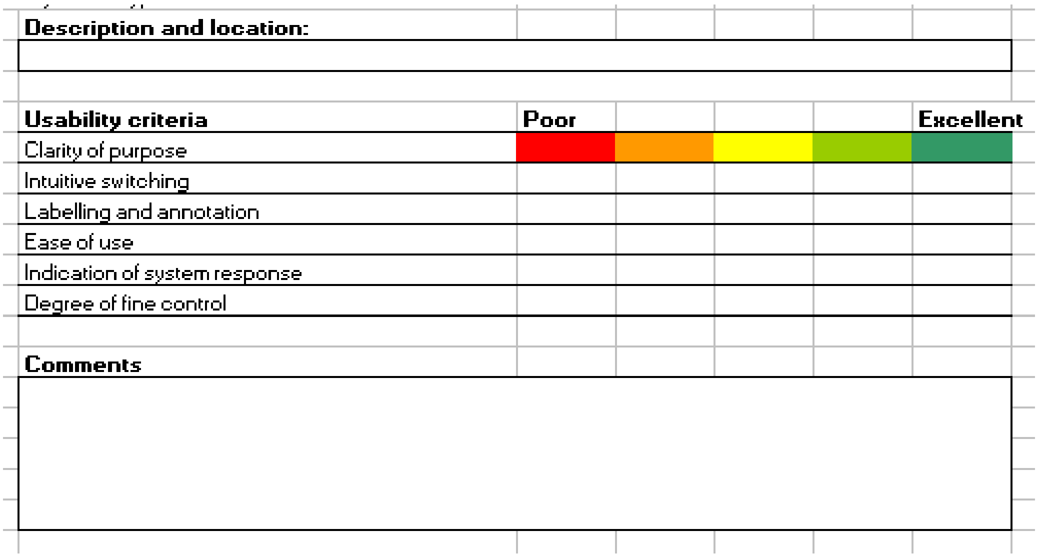
RECOMMENDATIONS

1. ***Maintain good daylight quality in developments***
2. ***Maintain good standard of customer care and review handover procedure to improve understanding of the use of the ventilation system and its maintenance requirements. Allow for hands on experience of systems by customers during handover.***
3. ***Collect all defect lessons learnt on the project (e.g. unexpected movement cracks on lanterns, door threshold leading to leaks, window leaks) and feedback to future projects. Communicate lessons to design team.***
4. ***Review space standards for bedrooms in larger (4 bedroom) properties.***
5. ***Review provision of full height windows in bedrooms against privacy.***
6. ***Review design and look of energy efficient light fittings provided to encourage occupants to keep them in place. Provide full information on where to find the correct lamps for all light fittings.***

7. ***Review location of washing machine in dwellings to avoid tight spaces and vibration carrying through the house.***
8. ***Consider needs for cleaning high ceilings and other high level features (e.g. lantern, rooflights). Review opening procedures for rooflights.***
9. ***Review overheating potential of dwellings, consider provision of shading and thermal mass and review ventilation strategy. Ensure customers understand what controls are provided to ventilation system (summer bypass).***
10. ***Review position of MVHR in all unit types and ensure full access to filters and control panels is provided. Remember need to fully open the unit to access the heat exchanger and avoid clashes with door frames et al. Position control switches in logical positions (e.g. boost in kitchen).***
11. ***Consider retraining of existing occupants on MVHR features to include hands on experience on cleaning of both filters (regular requirement) and heat exchanger (needed every two years) and all menus of the control panel – to give familiarity of the meaning of symbols and understand how to set and cancel boost and summer bypass modes.***
12. ***Review noise specification standards for internal partitions.***
13. ***Consider provision of power and lighting to garages.***

9. User Control Interfaces

9.1. This section covers the review of the control interfaces for heating and hot water controls, MVHR controls, electrical equipment controls, kitchen appliances, external skin touch points, water services controls and other miscellaneous touch points encountered in the houses at Avante, in particular in the study plots 44 and 39[12] (see appendix viii). The detail review follows the Building Controls Industry Association (BCIA) guidance collected in their *Controls for End Users* publication and ranks each of the usability criteria from poor to excellent on a five point scale (see figure 3 below). The usability criteria considered are clarity of purpose, intuitive switching, labelling and annotation, ease of use, indication of system response and degree of fine control.



Description and location:

Usability criteria	**Poor**				**Excellent**
Clarity of purpose	🟥	🟧	🟨	🟩	🟩
Intuitive switching					
Labelling and annotation					
Ease of use					
Indication of system response					
Degree of fine control					

Comments

Figure 3 Typical review of control interfaces table

9.2. The review of control interfaces study for Avante is summarised in relation to a number of key findings.

9.3. **The usability of the heating and hot water controls is not intuitive and needs instructions to use it properly**. Clarity of purpose is and quality of labelling could be improved. The degree of fine control and the indication of the system response is better as the house temperature changes. It is difficult to quickly find out if there is a problem which item(s) have failed. The interactions of the four elements (programmer/

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[12] Photos illustrating the control interfaces are from either of these two plots, the study plot no44 and plot 39 where the handover demonstration took place.

boiler control/ room thermostat and TRVs) need also to be communicated to users to improve energy efficiency - continuous heating (as suggested at handover) may not be the best for non thermally massive timber frame construction.

9.4. **The MVHR system is not intuitively understandable, the purpose is not clear, labelling and annotation is confusing, the control panel is difficult to use and needs the manual for any interaction. There is little indication of the system response or whether any fault is occurring.** It would be useful to have a set of simple instructions located by the MVHR panel (such as a sticker as in the heating programmer). Clearer labelling needs developing. A disappearing symbol timing the filters maintenance over set intervals is not very useful. There is no light or other indication when they actually need cleaning/ washing or hoovering. Access to the heat exchanger for cleaning (every two years) is not obvious. It is not easy to know how to set the summer bypass option without the manual. A comprehensive hands-on demonstration of the system to users is required.

9.5. **Light switches and consumer unit are intuitive to use and have good labelling and annotation.** The only comment is that when the lid of the electric panel/consumer unit is closed it is not obvious what is inside it or how to open it - a clear lid would be better. Changing light bulbs is not very easy for recessed fittings and some light switches were in awkward positions.

9.6. **Kitchen appliances labelling seems clear except for the gas hob where it is difficult to see which symbol fits what ring**. There is little indication of the purpose of the carbon filter cooker hood and it is unclear why various speeds may be needed for such filter. Oven labelling is much more obvious. It is good to have the gas stop lever for cooker close to the unit but clearer labelling needed to clarify its purpose and care should be taken not to obstruct it or knock it when the cupboard fills up.

9.7. **Windows and doors purpose is clear.** The locking mechanism for the door (lifting the door handle to engage locks) is not particularly intuitive but it is becoming more common. Rooflights operation is either by switch (lantern) or manual. The switch is not clear and does not give any indication of response. **Operation of rooflights with a pole is very awkward and difficult.**

9.8. **Hand basin taps are clearly labelled and easy to use** but taps are not so clear in the kitchen. Shower and bath controls have a good degree of fine control but switching is does not seem intuitive. **WC flush has two settings (long/short flush) but difficult to decide which is which** - some issues were reported on the degree of fine control (does not always shut off properly). It is good to have the water stop cock under the sink (with clear label).

9.9. One of the TV aerial sockets is left unlabelled - unclear what it might be for. **Usability of the water top up loop and pressure valve is undermined by the difficult access and the gauge being upside down.** It is not an intuitive thing to have to do, so clear instruction would be needed.

RECOMMENDATIONS:

1. ***Consider usability when choosing all control interfaces – think about how clear the purpose of the item is, how intuitive its operation is, whether the labelling is clear, how easy it is to use, whether it gives indication of the system response and whether it allows for a degree of fine control.***
2. ***Discuss requirements for usability with manufacturers and provide feedback on their controls.***
3. ***Provide hands on training of customers of all systems and allow them to interact with the controls and ask questions as to how they find them.***
4. ***Consider improving the labelling of controls and provision of instructions nearer to the point of use – e.g. a set of clear instructions by the MVHR unit should remind the user what the symbols mean and what to do at different times of year for improved energy efficiency.***

10. Emerging lessons and key recommendations

10.1. This Initial Occupancy study has examined the performance of Avante from a number of angles in order to tease out emergent issues arising between different functions during each stage of the development process.

10.2. The six sub-studies considered within this report have revealed a number of key recommendations throughout this report for process and product development. These recommendations are now considered in relation to three development processes: design (D), communication (C), and feedback (F) and captured in the themes analysis table below. Emergent lessons are identified as they relate to the key challenges and opportunities identified from these studies.

10.3. Each of the overall emerging lessons and all the recommendations in the table need to be taken forward through a developing 'Soft Landings' framework for Crest which clearly assigns roles, responsibilities and tasks in relation these findings. This will help to ensure that the knowledge and understanding gained from this study is firmly embedded within the various product and service improvement processes within Crest.

10.4. There are a number of findings in this limited study which require further investigation:

- The party wall thermal by pass needs more investigation to understand exactly where the heat loss is in relation to potential air passageways.
- ***The air flow should be double checked for all MVHR units on the Avante development as these could be operating at up to 50% below standard settings***.
- Humidity levels should be checked to establish how serious occupant claims of a dryness in the internal air quality are.
- Acoustic testing of party walls may be necessary to corroborate occupant complaints about noise levels and investigation of the party wall detailing as built to establish possible sound pathways.
- Air infiltration levels need to be measured when the MVHR system is in operation in order to establish actual heat loss from the home when it is in use and to see if the SAP assumption is correct.

10.5. A further monitoring study over two years of a sample of key typologies in Avante would provide physical evidence to corroborate the findings of this study in relation to occupant perceptions, building performance and energy use.

Emerging lessons and key recommendations from initial occupancy study for Avante housing development

Recommendations ***Emerging lessons***	**Design v as built**	**SAP check and actual heat loss**	**User control interfaces**	**Installation and commissioning**	**Handover and guidance**	**BUS questionnaire and interviews**
DESIGN LESSONS						
1.Greater attention to fabric detailing in relation to airtightness, and thermal bridging.(D)	Increase design and detailing iteration for innovative features	Improve fabric detailing to move toward Zero Carbon homes, and airtightness, especially at junctions and penetrations Communicate consequences of thermal bridging and party wall details- design out Investigate and improve party wall detailing		Maintain adequate falls to all drainage features	Improved home user guide needed – simpler, more visual and bespoke	Review lobbyless entrances, lantern, open plan to remove draughts.
2. Greater understanding of thermal bridging required by design and construction teams (D)	Improve designer's understanding of detailing	Psi and Y values need to be better understood Utilise actual Y-values (thermal bridging) in SAP to avoid unnecessary costs				
3. Review performance of key areas (D)		Update as built SAP with actual U-values of products	Consider usability when choosing all control interfaces – think about how clear the purpose of the item is, how intuitive its operation is, whether the labelling is clear, how easy it is to use, whether it gives indication of the system			Review opening procedure for rooflights and need to clean high ceilings and other high features. Review kitchen layout, acoustic performance, durability of finishes and lighting, space standards

			response and whether it allows for a degree of fine control.			for bedrooms in larger properties, provision of full height windows in bedrooms, position of washing machine to avoid acoustic transference, need for power and lighting in garage Review all lessons from defects and feedback
4. Consider weight of windows, doors and improve hinges + seals (D)	Allow for additional weight of lantern, windows, doors	Door and window movement				Improve door and window draught seals
5. Usability of all user interfaces need early consideration.(D)			Discuss requirements for usability with manufacturers and provide feedback on their controls		Home user guide to include simple explanations of controls specific to the property	Consider usability of all user interfaces at design stage Review position of MVHR for access to filters and control panel.
COMMUNICATION LESSONS						
6. Improve user guidance in relation to MVHR and heating systems(C)			Provide hands on training for occupants and ask how they feel about the controls during the demonstration Improve labelling of controls		Additional training for Home Demonstration staff in relation to MVHR and heating systems	Prepare user guide in tandem with design drawings to help identify user issues with design Provide more training for Home Demonstration staff and occupants, review guidance especially for MVHR summer bypass.
7. Develop greater dialogue between design team, developer and suppliers to ensure co-ordinated and detailed services plan (C)	Provide co-ordinated and detailed services plan More formal involvement of the design team beyond design stage to aide auditing and co-ordination			Locate MVHR boost switches, boiler flues in appropriate positions minimise flexible ductwork for MVHR		Evaluate responses and provide additional requirements where necessary.

8. Ensure robust installation and commissioning processes are built into tender documentation – evaluate and augment as needed. (C)	Develop greater dialogue between design team, developer ,suppliers in relation to installation, commissioning ,guidance especially for MVHR			Ensure installation and commissioning staff are trained and certified. Identify competent persons for installation and commissioning processes.		Ensure robust installation and commissioning processes for heating and ventilation are in tender documentation.
FEEDBACK LESSONS						
9. Feedback evidence-based learning into briefing(F) ***10. Provide clearer guidance to design team on user requirements (F)***	Feedback learning from recorded evidence into inception and briefing process					Provide clearer guidance to design team on user requirements
11. Ensure proposed site changes are reviewed and documented (F)	Ensure all changes on site are thoroughly reviewed with design team and documented					Keep usability in mind when changes on site occur
12. Realistic heating regimes require accurate SAP modelling, user understanding of controls, and thermal mass to avoid overheating. (C,D,F)	Design for realistic heating regimes	Use SAP to design for ventilation and heating demands SAP modelling needs improving -can be overly conservative		Advise users on default positions for heating and ventilation and how to optimise these controls		Include more thermal mass to avoid summer overheating. Review overheating potential of dwellings and consider the provision of shading, thermal mass.
		Design/client team to check SAP assessment assumptions and advise /update accordingly Investigate heat loss when MVHR is running				

Glossary

Psi –value: the *linear* thermal transmittance through a material or combination of materials.

Thermal bridging: the heat lost through a particular element of the external fabric which has less insulating properties than the elements surrounding it.

Y-value: the total heat loss attributed to the linear thermal transmittance divided by the surface area of the thermal envelope considered.