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The interaction between domestic occupants and Mechanical Ventilation and Heat Recovery (MVHR) system performance

Deborah Haynes[1], Andrew Farr and Frances Hill[1]

1 MSc Architecture: Advanced Energy and Environmental Studies, Graduate School of the Environment, Centre for Alternative Technology, Machynlleth, Powys SY20 9AZ

Abstract

This case study examines MVHR functioning in the UK, and how occupants of domestic dwellings are using, learning about and maintaining these systems. Previous research suggests poor performance of systems which is an issue for increasingly airtight buildings.

Five dwellings in an energy efficient housing development were assessed using a mixed method approach. Air flow related performance reflected previous research as some systems met Building Regulations extract rates and/or appropriate balancing levels, but others didn't. Energy use and Heat Recovery efficiency was also variable and other issues were ascertained by surveys.

Interviews established patterns in the levels of understanding and highlighted the importance of 'easy to use' controls and the benefits of varied information formats for new home owners rather than a 'one size fits all' approach. The vast array of design, commissioning and installation related variables highlight that, for MVHR to perform well, the entire construction industry must take responsibility.

Keywords: MVHR, ventilation, domestic, technology, occupant understanding

1. Background and Literature Review

1.1 Ventilation in the UK

The standard UK requirements for ventilation are detailed in Part F of the relevant (2006) Building Regulations and classified as "the *supply and removal of air (by natural and/or mechanical means) to or from a space or spaces in a building. It normally comprises a combination of purpose provided ventilation and infiltration".* When applied for MVHR in the studied properties, this translates for extract ventilation as 21 litres/sec (l/s) for the normal/low ventilation rate. Additionally, for raised ventilation (ie boost during cooking or bathing) it is 13 l/s for kitchen, 6 l/s for WCs and 8 l/s for bathrooms. (Great Britain. HM Government, 2010, p8). This is particularly important due to other recent changes to Building Regulations requiring increased airtightness of 10 $m^3/(hr.m^2)$ at 50 Pascals (Pelsmakers, 2012).

Whole house MVHR systems provide ventilation through extracting moist air from extract vents in the kitchen and bathrooms, and supplying fresh air to the house through supply vents in other rooms. Heat recovery is an important function of MVHR as it reduces the heat that is otherwise lost when stale air leaves a property. Inadequate air tightness levels affect this system's efficiency (Mawditt, 2012).

Appropriately designed ventilation that is used properly is vital in modern buildings to achieve good indoor air quality (Soldaat and Itard, 2007). However, good practice in MVHR design, commissioning and installation is widely cited to be the exception rather than the rule, an issue that affects the efficiency and operation of the system (Farr, 2012; Zero Carbon Hub and NHBC Foundation, 2012).

1.2 Occupants and technology

Whilst many problems seen with MVHR functioning are due to poor design, installation and commissioning (Bell et al, 2010), an emerging area of research is that of occupant understanding, behaviour and interaction with technologies (Stevenson and Rijal, 2010). User behaviour can hugely affect energy use in a building and indoor air quality (Sunikka-Blank and Galvin, 2012), and the success of technological fixes for energy saving is dependent on occupants. New buildings can, in reality, use triple the amount of energy predicted which explains the current push to understand the effect of human behaviour on domestic housing performance (Stevenson and Leaman, 2010; Stevenson and Rijal, 2010).

A number of researchers refer to a general need for better information that is meaningful to users and not confusing (Foulds et al, 2012; Bell et al, 2010). Prior observation-based research on the studied developer's handover to the new owners highlighted the demonstrator's "*worrying lack of knowledge"* (Project Academic et al, 2012, p7). Easy to use and understand controls are vitally important, preventing potentially incorrect assumptions and 'learning by doing' (Foulds et al, 2012). Bordass et al (2007) have summarised the needs of end users from controls in a commercial context and this was adapted in the interviews for this study.

2. Research methods

A case study used a mixed method approach to:

1. Give a snapshot quantitative assessment of current functioning and common problems in an energy efficient build.

2. Investigate five occupants' knowledge, maintenance and use of MVHR using a qualitative semi-structured interview approach (pretested questions by Behar, 2012)

A low energy housing estate with developers who were keen to utilise findings on MVHR in the next construction phase was used. Data was also available from a project academic and the development is anonymous. The homes are all owner occupied and were built to Code for Sustainable Homes level 4 standard. The official model names of the MVHR systems have been replaced by the labels 'System X' and 'System Y'.

2.1 Quantitative data: MVHR surveys and data logging

Other data collected from the project academic looked at MVHR energy use and temperature data that could be used to assess heat recovery function. All quantitative data collected and implications for MVHR functioning is detailed in Table 1:

Table 1: Measurable data and implications for MVHR functioning

Assessment method	Data	MVHR functioning implications
Survey – air flow speeds using a Sweena Flow 233 and windshield	Air flow rate in l/s at all internal supply and extract valves and for external intake and exhaust	Does internal extract rate meet Building Regulations? Is supply and extract balanced?
54 days of data logging from 3 homes	MVHR energy data in kWh – daily averages, half hourly	Excessively high may indicate a problem
31 days of data logging from 2 homes	Half hourly data gives daily average temperatures of incoming fresh air, exhaust air and 'pre warmed air'	Temperature efficiency of the Heat Recovery systems using the equation TE = (T4 - T3)/(T1-T3)x 100[1] (Nicholls, 2008).

2.2 Qualitative data: Semi structured interviews

5 interviews were conducted with homeowners, as summarised in Table 2:

Table 2: Qualitative data and implications for MVHR functioning

Data	MVHR functioning implications
Use, information and knowledge of MVHR including filters and maintenance, design and use of controls, functioning of the system and indoor air quality.	Classify resident with one of three levels of understanding. Supporting information on control use, filters and maintenance, system functioning and indoor air quality

Detailed surveys carried out raised other construction and maintenance related issues that, while not directly measurable, were useful indications of MVHR functioning and use.

3. Results

3.1 MVHR systems performance and common problems

The researched housing estate was compared against the air flows under the 2006 Building Regulations (Great Britain, HM Government, 2006). There seemed to be a difference in this basic performance between the two MVHR systems, with System X achieving the Building Regulations in around 69% of instances, and System Y in 0% of cases (Table 3). Overall, this represented achievement of Building Regulations for only 29% of total air flow measurements. This assumed boost ventilation during bathing and cooking although interviews showed that this was only happening for two households out of five for each practice, a source of further under ventilation.

Using 10% imbalance in air flow rates as the maximum acceptable,one System X was balanced and one wasn't. All System Y balanced only at the increased fan speed. The overall 50% balancing rate in the current study is a similar level to Hill (1999)'s 46% figure.

In the two System Y-using properties, data gave Heat Recovery temperature efficiencies of only 46 and 49% against manufacturers' stated 89%. Limited data on air tightness implied that this would further increase the inefficiency of this system (Mawditt, 2012)

[1] T1 is Warm air from the house before reaching the AHU, T3 is Fresh air in from the exterior and T4 is Warm air into the house from the AHU.

Energy use was found to be much higher in the System X property data logged at 2.23 kWh per day as opposed to 0.34 and 0.42 kWh per day in System Y.

Table 3: Functioning of systems

Dwelling number	MVHR system	% meeting Building Regulations	Within 10% imbalance boundary (FS = Fan speed)	Heat Recovery Efficiency	Average daily electricity use of MVHR (kWh)
A	X	50	Yes for all	No data	2.23
B	X	87.5	No for all	No data	No data
C	Y	0	No –FS1, Yes – FS2	49%	0.34
D	Y	0	No –FS1, Yes – FS2	46%	0.42
E	Y	0	No –FS1, Yes – FS2	No data	18W (0.43)

The MVHR air flow certificates were not independently commissioned and unusually matched the Building Regulations exactly so were very likely to be false. Other design, installation and construction related issues identified from surveys and interviews are shown in Table 4 along with possible reasons and implications for building ventilation:

Table 4: Other performance related issues brought up at survey stage

Issue	**Number of instances**	**What means for ventilation**	**Reason for issue**
Air valves too close to doors	In majority of rooms in all 5 homes	Create air movement 'dead zones'	Change of design at 'build' stage
Under door airflow paths too small	Varied but common issue in all homes	Air flow rates reduced	Less than 10mm space under doors
Noise may cause under ventilation	Three including both System X	Residents often kept low fan speed on	Number of design/installation
Filters soiled and poorly fitting Filters missing or incorrectly fitted	Two System X Two System Y (other not checked)	Negatively affects air flow rates	4 out of 5 residents aware of need to clean or change but not perceived as a priority

Despite the obvious issues and underperformance of these systems, residents seemed generally positive about indoor air quality at interview, all giving examples of low relative humidity although two felt unsure that the 'system was performing'.

3.2 Occupant Understanding of MVHR systems

Supporting Project Academic et al's (2012) findings, two occupants found the handover of limited use and all but one stated how difficult they found the large amount of information they were given to use. Whilst all users tended to follow basic operating instructions and seek more information from 'knowledgeable others', three distinct levels of understanding and knowledge on the system were found which were called 'basic' (2

occupants), 'medium' (2 occupants) and 'complex' (1 occupant). This is in line with previous findings (Behar, 2012; Foulds et al, 2012).

Different residents would have preferred different additional types of material. A better system demo, more written instructions, and a telephone helpline were requested by two with one asking for a fuller set of MVHR information. There is clearly no "one size fits all" solution but access to knowledge on the system that suits individual needs is clearly key. Three different controls were used in the five properties. Using criteria from an adapted version of BSRIA Guidance (Bordass et al, 2007), all users stated that they found their controls easy to use and understand. However, for accessibility and tangible feedback, System Y Phase 2 controls performed best, a remote control with LED lights.

4. Discussion and Concluding Remarks

Most, if not all, performance related issues of the MVHR systems investigated could be considered as related to design, installation, commissioning and maintenance. However, because of the vast, interactive nature of many variables involved, it was not possible to clarify a single cause for poor functioning of each system.

The Design and Build approach used by the developers is generally difficult to manage – this is intensified when new technologies are brought into the mix (Morton, 2012), and builders/installers are not familiar with the specific installation and location requirements of MVHR valves, ducting etc. Therefore, communication between professionals is vital, requiring a move out of the traditional construction silos to discuss projects interactively with installation-related elements being made clear to contractors (Farr, 2012). Despite residents' apparent knowledge of the need for cleaning or replacement of filters, issues were found with filters in four out of five homes, echoing previous research (Crump et al, 2009).

Consideration of end user in construction based product design, controls and information giving is key, particularly with new challenging technologies (Foulds et al, 2012). As a minimum, controls need to be appropriately sited, and easy to use understand, and get feedback from (Bordass et al, 2007).

This study supports existing research into the need for information to be given to new residents in a better, more meaningful format (Foulds et al, 2012; Bell et al, 2010). As this varies for each person, making different levels of information available in addition to human interaction possibly via a 'Soft Landings' approach during building handover would appear ideal (Project Academic et al, 2012; Usable Buildings Trust and BSRIA, 2009).

Following a research debrief, the Project Developers will ensure involvement of the architect and developer as well as independent MVHR commissioning throughout the design and build. They are also getting an 'expert' to carry out walk round handovers. The MVHR installers/suppliers of the systems investigated have rebalanced and checked the offending systems as a result of this investigation.

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