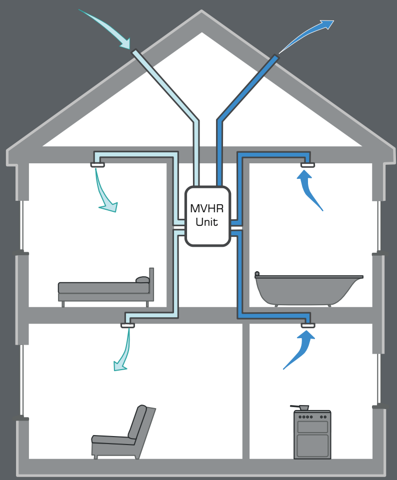

MECHANICAL VENTILATION WITH HEAT RECOVERY IN NEW HOMES

FINAL REPORT

VENTILATION AND INDOOR AIR QUALITY TASK GROUP

July 2013

Zero Carbon Hub

The Zero Carbon Hub was established in 2008 to support the delivery of zero carbon homes from 2016. It is a public/private partnership drawing support from both Government and the Industry and reports directly to the 2016 Taskforce.

To find out more or if you would like to contribute to the work of the Zero Carbon Hub, please contact info@zerocarbonhub.org

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NHBC Foundation

The NHBC Foundation was established in 2006 by NHBC to deliver high-quality research and practical guidance to help the industry meet its considerable challenges.

Since its inception, the NHBC Foundation's work has focused primarily on the sustainability agenda and the challenges of Government's 2016 zero carbon homes target.

The Zero Carbon Hub is grateful to the NHBC Foundation for its support in the dissemination of this guidance.

Further details of the latest outputs from the NHBC Foundation can be found at www.nhbcfoundation.org

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Foreword

In my past roles as chair of Building Regulations Advisory Committee working parties on Part L (conservation of fuel and power) and Part F (ventilation) I was acutely aware of the balance that needs to be struck between reducing energy consumption in homes, whilst at the same time maintaining a healthy indoor environment.

Over the past three years, the VIAQ Task Group has been reviewing the health implications that can be associated with poor indoor air quality, against a background of new homes becoming much more airtight. Specifically we have reviewed current practice in relation to mechanical ventilation with heat recovery and evidence from homes in which it has been installed.

Sadly, much of the evidence points to a range of issues that need to be addressed with design, installation, commissioning, operation and use. But on a more positive note, evidence is beginning to emerge from 14 Passivhaus homes, which would appear to confirm that the exacting requirements of this German standard are reaping rewards in some occupied homes.

Further monitoring from various projects is ongoing, including from the Technology Strategy Board programme, and this will be invaluable in furthering our understanding and identifying necessary actions.

Whilst this report concludes the work of the VIAQ Task Group, there is much more to be done to ensure good performance of MVHR in people's homes and we make recommendations for further concerted action to deliver this goal.

I am very grateful to members of the Task Group for their valuable time and expertise. A special thank-you goes to SSE and the occupants at Greenwatt Way, and for all the project contributions received since we published our Interim Report.

Lynne Sullivan, OBE

Chair, Ventilation and Indoor Air Quality Task Group

Contents

Foreword 1

1 Executive summary 3

2 Background 4

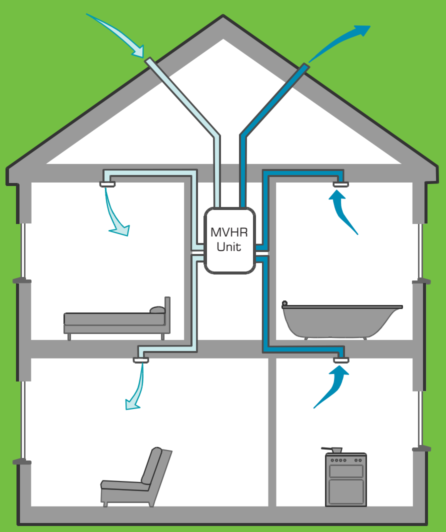
3 Additional evidence reviewed 5

4 Conclusions & recommendations 9

References 13

Mechanical ventilation with heat recovery

MVHR is a multi-room ducted system that combines supply and extract ventilation in one solution. It continuously provides fresh air to habitable rooms whilst pre-warming it with recovered heat from the extract air which would otherwise have been vented outside and therefore lost.



Warm moist air is extracted from wet rooms such as bathrooms and kitchens through ductwork to a central unit. Supply ventilation air from outside the home is passed through a heat exchanger in the central unit and warmed by the heat in the extract air. MVHR systems are able to recover around 90% of the heat that would otherwise be lost (measured in accordance with the 2005 SAP Appendix Q test). The warmed air is then distributed throughout the home by ductwork. Air valves at ceiling level ensure that draughts are avoided.

The system runs most of the time at a low background rate but when more rapid ventilation is required because of increased moisture generation (caused for example by cooking, or extra density of occupation) the system is switched to a boost rate, either manually or by sensor control.

1 Executive summary

The move towards higher levels of energy efficiency of new homes, improved airtightness and increased use of mechanical ventilation with heat recovery (MVHR) systems have caused concerns to be raised about indoor air quality and possible effects on health.

Set up in 2010 to consider the associated issues in detail, the Zero Carbon Hub Ventilation and Indoor Air Quality (VIAQ) Task Group issued its Interim Report in January 2012. Using additional evidence that has emerged since then, the Task Group met again in March 2013 to complete its review and make final conclusions and recommendations, which are summarised as follows:

1 Airtightness, indoor air quality and health

A variety of airborne pollutants are present in homes and some are associated with serious health effects, including asthma, lung cancer, chronic obstructive pulmonary disease and cardiovascular disease.

As new homes become more airtight, adequate ventilation is relied upon increasingly to maintain satisfactory indoor air quality(IAQ). It is essential that ventilation systems of all types successfully deliver adequate indoor air quality, but as the number of MVHR systems being installed continues to grow and due to its relative complexity, there is a need for particular attention to this type of system.

2 Evidence base

The Task Group was able to identify only limited evidence from installed, monitored MVHR systems in recently constructed homes. However, almost all of the evidence that is available points to a range of issues which need to be addressed to make sure these systems work in practice. The Task Group recommends that further research should be undertaken by Government to inform future amendments to Building Regulations guidance and ensure public health and safety.

3 MVHR good practice guidance

The Task Group believes that there is considerable scope for improvement in current practice in respect of design, installation, commissioning, operation and maintenance of MVHR. Whilst noting the positive progress of NHBC in developing NHBC Standards guidance for MVHR, the Task Group recommends concerted action should be led by Government, to develop and further promote good practice.

4 Source control

Building Regulations and other mechanisms have a role to play in reducing emissions at source. The Task Group recommends that further consideration needs to be given to how volatile organic compound (VOC) emissions in particular can be controlled in this way and consumer awareness increased.

2 Background

Changes to Approved Document L (Conservation of fuel and power) of the Building Regulations in 2006 encouraged a focus on improved airtightness for new homes and introduced sample air permeability testing to help ensure that this is achieved in practice. Alongside improved airtightness, increased energy efficiency, driven by both Approved Document L and the Code for Sustainable Homes, have encouraged the use of mechanical ventilation with heat recovery (MVHR) as a cost-effective specification for satisfying both energy efficiency and ventilation requirements.

Concerns shared by industry representatives around that time led the NHBC Foundation to commission desk-based research into this area. *Indoor air quality in highly energy efficient homes – a review* **(1)**, published in 2009, reported on existing research. It helped us to understand the variety of pollutants present in homes and also their potential connection with a range of health conditions. It also raised concerns about the effectiveness of MVHR in maintaining healthy indoor environments.

In response to the concerns raised, the Zero Carbon Hub Ventilation and Indoor Air Quality (VIAQ) Task Group was convened and first met in September 2010 to consider these in greater detail. The Task Group comprises experts representing a wide variety of interests including, housing design, house building, ventilation, research and academia as well as Government officials (see inside front cover for membership). Four meetings of the Task Group were held prior to the publication of the Interim Report **(2)** in January 2012.

Whilst making wide-ranging interim recommendations, the Task Group noted at that time that the evidence base was limited but that various projects in progress had the potential to contribute useful data to our work. The progress of these has been monitored since and the VIAQ Task Group met again in March 2013 to review the additional evidence emerging from these projects and from other sources.

This report presents a summary of the additional evidence from these projects and other information that has been gathered along the way, and details the final conclusions and recommendations of the VIAQ Task Group.

3 Additional evidence reviewed

This section summarises the additional material reviewed by the Task Group since publication of the Interim Report.

Arun Crescent

This Saxon Weald Homes project [3] undertook monitoring of heating and MVHR systems installed in 6 new houses in Billingshurst, West Sussex from September 2009 to January 2010. According to the housing association, the installation in one house was so poor that it never worked; all others worked intermittently as a result of both poor installation and tenant misuse i.e. turning the system off or not cleaning the filters. All six MVHR units have subsequently been replaced with a completely different make and model and issues with the systems have been reduced considerably.

Good Homes Alliance monitoring programme

This programme [4] is undertaking post-completion and post-occupancy monitoring of four homes on three sites of which three homes have been fitted with MVHR. The analysis and reporting have not yet reached a conclusion, but there appears to be large variability in the performance of heating and ventilation systems.

There have been issues with some of the original commissioning, the research team's own measurements differing significantly from designed rates. It would also appear that there have been problems with the summer bypass mode - duct temperature readings indicate that it is not operating in one dwelling in which it has been installed.

Greenwatt Way

Findings from this SSE project [5] are presented in the case study on page 6.

Rowner Renewal Project

This Technology Strategy Board Building Performance Evaluation project [6] is evaluating the design, construction and performance of two blocks of twelve flats built to energy efficiency standards better than Building Regulations (ADL 2006), all fitted with MVHR systems. Various issues were noted with the design/installation of the MVHR systems, including the excessive use of flexible ductwork, installed with sharp bends, which increase air resistance and reduce efficiency. Also, the ductwork was not insulated to an adequate standard, which could cause problems with heat loss and/or condensation.

Post-occupancy monitoring is indicating satisfactory indoor thermal conditions throughout, with CO_2 concentrations and humidity levels within normal limits. Measurements of the MVHR systems' energy consumption indicate figures similar to those predicted by SAP and the manufacturer. A building use survey conducted on site revealed issues around people's understanding of the MVHR system and the use of the boost mode. However the occupants' overall satisfaction at the site appears high.

Case study: Greenwatt Way

These ten homes were built by energy supplier, SSE, in 2009 on an ex-industrial site in Chalvey, near Slough, Berkshire. Achieving Code for Sustainable Homes Level 6, the homes were conceived as a way of improving SSE's understanding of domestic energy generation and use in homes of the future.

In one corner of the site is the 'energy centre' which provides for the space and hot water heating requirements of the homes (by means of a biomass boiler, ground and air source heat pumps and solar thermal panels). In addition electricity is generated from solar photovoltaic tiles fixed to the roofs of the homes. Six of the homes (four houses and two flats) are of masonry construction and the other four are timber frame houses.

The ventilation aspects of the Greenwatt Way development formed the basis of an NHBC Foundation and Zero Carbon Hub study, undertaken by BRE. The homes achieved a good standard of airtightness, with results of between 2.6 and 5.7 $m^3/h/m^2$ at 50 Pa measured at completion. Ventilation to each of the homes is provided by means of an MVHR system, with fan units located within the roof spaces.

The homes were completed in September 2010 and occupied immediately after by employees of SSE and Slough Borough Council nominees, all of whom agreed to participate in the research. Homes were monitored for a period of almost two years post-occupation, which spanned two heating seasons during which external temperatures fell to well below zero for extended periods.

Design

From the earliest stages of design, poor decisions were taken that would limit the effectiveness and efficiency of the installations, such as the same MVHR fan unit model being selected for all homes, regardless of their size (one-bedroom flat to three-bedroom house) and the MVHR units and much of the ductwork being installed outside of the insulated envelope in the loft. Also the original outline design was never worked up into a proper detailed design.

Installation

Although the installation was neat and tidy, a variety of issues were present: there was no mechanical isolation between the fan unit and the rigid ductwork, which allowed for vibration to be transferred; unnecessarily long lengths of flexible ductwork were used, reducing efficiency; inadequate provision was made for condensation to be drained from the system; and 'extract-type' air valves were used throughout, rather than both 'inlet-type' and 'extract-type'.

Commissioning

There was clear evidence that commissioning had not been carried out correctly and all units inspected were running in boost mode constantly (at near-maximum fan power); proper controls had not been provided; and filters were clogged with construction dust at the time of handover.

In-use performance

The installation of the MVHR systems outside the insulated envelope had an adverse effect on their thermal performance. Because a frost protection function was not provided, the heat exchangers froze during very cold periods and caused very cold air to be delivered into the homes. In addition, occupiers complained about noise levels.

Wimbish Passivhaus

Probably the most encouraging evidence came from this development of 14 houses and flats in north-west Essex for Hastoe Housing Association **(7)**. These homes were designed and constructed to the German Passivhaus very low energy standard **(8)** to a tight budget and so far monitoring data has been gathered for about 20 months post-occupation.

The MVHR systems installed generally appear to be delivering humidity levels within normal limits (although marginally low in some houses at the end of each winter). Indications are that perceived indoor air quality is satisfactory and that the systems are operating efficiently – the heat recovery efficiency of the MVHR systems is running at about 87%. Good practice was observed with the installation of the MVHR fan units within the thermal envelope of the homes.

Hastoe Housing Association has learned some useful lessons about how MVHR should be explained to occupants (all being members of the general population and without special knowledge of or interest in Passivhaus). There was varying feedback on the appropriateness of controls, with occupants' needs varying according to age, gender and technical ability. They are also learning the importance of filter changing at six-monthly intervals.

Leeds Metropolitan University

Colleagues from the Centre for the Built Environment (CeBE) at Leeds Metropolitan University provided summary information from their research and testing work, which confirmed many of the issues reported in the interim report, including poor standards of design and installation **(9)**. These include systems where supply and extract air valves are positioned too close together and therefore fail to ventilate the whole room.

However, of particular concern is the inadequate standard of commissioning that they commonly encountered. Sometimes multiple attempts have been made before systems achieved the ventilation rates of Approved Document F (ventilation), and there were significant discrepancies between what is recorded on commissioning certificates and the measurements obtained by researchers shortly afterwards. They also point to the inaccessibility of controls and indicators fitted to MVHR fan units located in the roof space.

Mechanical ventilation in recently built Dutch homes

A paper published in 2012 **(10)** outlines the experience of MVHR and mechanical extract ventilation (MEV) systems, which have been fitted to nearly all new homes, built in the Netherlands in the last ten years. Following media coverage of concerns related to the health effects of these systems, the Dutch Ministry of Housing, Spatial Planning and the Environment commissioned a study into their performance. The study included the inspection of 150 homes with MVHR.

The overall conclusion from the study is that 'many things go wrong in standard Dutch housing projects with mechanical ventilation' (both MVHR and MEV). The common problems include:

- Insufficient ventilation capacity: about half the homes have at least one room with insufficient ventilation
- Noise: noise from the ventilation system exceeds the reference value in more than half the homes with MVHR, especially in bedrooms

- Unclean ventilation system: dust and dirt were found in the air supply ducts of two thirds of homes and with MVHR; the MVHR fan unit was internally dirty in a third of the homes

- Incorrect design or installation: ductwork not properly installed (e.g. with unnecessary bends) and supply air valves were not placed in optimal locations

- Incorrect use: most users were not operating systems as recommended, many not knowing what their recommended use is.

The usability of control interfaces in low-carbon housing

Some of the difficulties associated with the control of MVHR have been highlighted in a recent paper **(11)**, which notes that the purpose of MVHR may not be intuitively understood by occupants. It points to inadequacies with labelling and annotation of controls that may be located without adequate access, and to limited feedback given to users on the operation of the system.

The paper calls for a more user-centred approach to the design, installation and handover of control products to ensure their usability in practice.

4 Conclusions & recommendations

4.1 Airtightness, indoor air quality and health

As stated in more detail in the Interim Report, a variety of airborne pollutants exist in homes, many of which are likely to be at their highest levels in newly-built and newly-refurbished homes. The trend towards greater levels of airtightness may well tend to exacerbate pollutant levels. Also drying-out periods may be extended, with elevated humidity levels lasting for a longer period.

Based on the review of a number of international studies, there is little doubt that poor IAQ is connected with a range of undesirable health effects such as allergic and asthma symptoms, lung cancer, chronic obstructive pulmonary disease, airborne respiratory infections and cardiovascular disease.

This reinforces the need for the design, construction and commissioning of buildings to be undertaken with IAQ firmly in mind so that adequate ventilation is provided (regardless of type of system).

According to BEAMA, 24,000 MVHR fan units were installed in the UK in 2012, mostly in new homes, and this increasing trend is expected to continue. However, the Task Group reviewed much evidence of issues that have arisen with design, installation, commissioning, operation and maintenance.

To ensure that the energy/CO_2 benefits of MVHR are delivered alongside good IAQ, and to avoid any adverse consequences, detailed attention must be paid to all aspects of these systems.

4.2 Evidence base

Judgements about the use of MVHR are currently based on limited evidence. The Interim Report noted the Task Group's concern at the lack of monitoring data for MVHR that was available at that time and the additional evidence that has become available since its publication is also limited.

Given the weight of evidence suggesting that all is not well, the potential for poor IAQ and health issues, and the potential for any energy/CO_2 benefit not to be realised, the Task Group considers that there is a need for further monitoring of MVHR systems in use post-occupancy. The Task Group recommends that further monitoring should be undertaken as part of Government research activity to inform future revisions to Approved Documents F and L.

A major meta-study currently underway **(12)** is expected to provide much-needed quantitative data on the performance of MVHR systems and their maintenance and use. It is hoped that outputs from this work, funded by the Technology Strategy Board and programmed for completion in 2014, will help improve standards of specification, installation, commissioning and maintenance, and inform the direction of future research.

4.3 MVHR good practice

The overwhelming majority of the evidence reviewed confirmed significant weakness in current MVHR practice. In order that the potential benefits of MVHR can actually be delivered and IAQ problems averted, MVHR practice must improve. The Task Group recommends the following good practice (noting that much applies also to other ventilation system types).

Design

System design It is essential that the original design is undertaken by a competent designer in accordance with manufacturers' guidance and established good practice and that any proposals for re-design that may arise during construction are also subject to proper approval. The intake terminal should be located to avoid sources of external pollution.

Type of MVHR fan unit Care needs to be taken to ensure that the MVHR unit selected is suitable for the specific home and the expected occupancy.

Location Careful consideration needs to be given to the location of MVHR fan units and ductwork, taking account of the following issues:

- easy access to the MVHR unit is essential to allow for filters to be changed (normally by the occupants) and for servicing and repair
- for maximum efficiency the MVHR fan unit and ductwork should be located within the insulated envelope of the home
- parts of the system that are located in unheated spaces should be insulated to a similar standard as the envelope of the home
- the two outside ducts should be kept short and they should be fitted with vapour-proof insulation to minimise condensation risk
- if an insect filter is fitted to the intake it must be accessible for periodic cleaning/replacement.

To ensure efficiency of operation and access it is important that these issues are considered at the earliest stages of design with homes being 'designed around the ventilation system'(13). It is unlikely that the loft will provide a preferred location in most cases, although other options may be more limited in smaller homes. Where the MVHR fan unit is located in the loft, suitable, safe access needs to be provided.

Noise MVHR systems should be designed to minimise noise generated in use in order to minimise nuisance and reduce the risk of occupants turning them off. Careful consideration should be given to the location of the MVHR fan unit in relation to bedrooms, providing acoustic isolation for the unit and the use of suitable mountings, appropriately sized ducts, etc.

Controls All MVHR systems should be fitted with visual indicators that clearly show that the system is working, whether it is in normal or boost and/or bypass mode and when maintenance is needed. For certain types of specialised housing an audible indication should also be provided.

A user-centred approach to controls should be adopted, with appropriate, simple user controls and indicators provided in sensible, accessible locations (e.g. not tucked away awkwardly inside a cupboard). They should be easy to use, and clear and intuitive for occupants. The controls for summer bypass and frost protection should operate automatically for different external weather conditions.

Advanced sensing controls (demand control ventilation) based on movement and/or humidity/CO_2 sensors would appear to offer the potential for maximising energy efficiency while ensuring that good IAQ is maintained.

Consideration should be given to the desirability of requiring automatic operation of the boost mode when cooking. This will help reduce indoor levels of particulates from food as it is cooked, as well as the products of combustion arising from the use of gas cooking appliances.

Installation

High standards of installation must be achieved for systems to work efficiently and safely. The installation should comply with the design and must ensure that systems are installed with the MVHR fan unit appropriately located and mounted and the ductwork correctly routed and connected.

Ductwork should generally be of rigid material, with flexible ducting being used only where indicated in the design. Insulation should be provided as shown in the design and care should be taken to ensure that the correct types of air valves are used for inlet and exhaust.

Condensate drainage must be installed to the correct falls and where connected to the soil and vent pipe, a (dry) self-sealing waste trap should be provided. Pipework should be insulated where necessary to protect against freezing.

As noted above, any proposals for re-design that arise during construction should be subject to proper approval by the system designer.

Commissioning

Evidence suggests that commissioning is a particularly common area of weakness, although clearly it is essential for the correct functioning of MVHR systems. Commissioning must be undertaken by a competent individual and the recommendations of the Domestic Ventilation Compliance Guide **(14)** should be followed. Care should be taken to ensure that the ductwork and filters are free from dust at handover.

User instructions and maintenance

User instructions currently issued with new MVHR fan units do not generally seem to be targeted at typical users. Work is needed by manufacturers to develop simple, clear guidance on operation and include recommendations on summer and winter operation and window opening.

Maintenance, including filter cleaning/changing is essential for the safe and efficient operation of MVHR. As a starting point, clear instructions should be provided detailing exactly what is required, supplemented by one-to-one explanation, tailored to the needs of the specific occupants. Increasing the availability of service contracts to look after these systems, post-occupation, would also be a welcome development.

How this can be achieved

The Task Group noted the good progress NHBC is making towards the development of a new chapter of the NHBC Standards dealing with MVHR, due for publication at the end of 2013 (effective from January 2014). This will provide a useful benchmark for the industry with the potential to significantly improve design and site practice in homes that are registered with NHBC.

The Interim Report recommended that the Domestic Ventilation Compliance Guide should be redrafted to take account of the interim recommendations, reformatted to include useful images. The Task Group considers that a pressing need for clear, accessible guidance for the whole industry still remains.

Competence within the industry remains a key issue, with the Task Group's concerns being heightened by overwhelming evidence that good practice is not being adhered to, in respect of design, installation and commissioning. The interim report made mention of the competency scheme approach being championed by BEAMA and noted the promise it showed at that time. Although BEAMA point to the many hundreds of installers who have now been trained through the BPEC scheme, regrettably the competency schemes have made little progress.

Members of the Task Group, including BEAMA, have called on DCLG to consider mandatory competency requirements for new build ventilation systems to drive uptake and standards. BEAMA has re-opened discussions with one competency scheme provider to launch a high profile campaign targeting new build specifiers and contractors in the summer of 2013.

Given the potential risks to the health and safety of the occupants of new homes, all possible avenues for ensuring that good practice is achieved as a matter of course should be fully explored and concerted action is required between government and industry.

4.4 Source control

The Interim Report made reference to the control of emissions at source and the lack of guidance provided on the topic in Building Regulations. The Task Group is not aware of particular progress in this area having been made in the UK since its publication and remains of the view that consideration should be given as to how Building Regulations and other mechanisms could be used to establish VOC emission requirements for construction products in new and refurbished homes and to increase consumer awareness of low emitting indoor products.

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