European testing programme investigating the operation of an innovative ventilation system for houses in temperate climates

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ABSTRACT
In northern Europe ongoing changes in legislation that require increased levels of insulation, and the sealing of houses to reduce infiltration heat loss, has led to concerns about indoor air quality. As a result there is a need to achieve regulated and energy efficient winter ventilation in houses. The system currently being tested ('WHOLE-pvs') in paired (test and control) houses and flats in Denmark, Poland and Ireland uses 'supply air' windows in combination with Passive Stack Ventilation. Unlike other methods such as Mechanical Ventilation Heat Reclaim which incorporates a constantly running fan, the WHOLE-pvs system is entirely passive. The pressure drop across the window is provided by the buoyancy and wind effects driving the Passive Stack Ventilation, whilst the window acts as a heat reclaim and passive solar device. The houses will be monitored initially unoccupied, and subsequently used to gauge tenant's reactions to the system. The work continues from previous studies carried out in test cells and verified by the use of computer simulations. This paper will describe the project and the houses and some initial findings. The project is being funded by an award from the EU 5th Framework Programme.

INDEX TERMS
Ventilation system; Heat recovery; Windows

INTRODUCTION
The health problems associated with inadequate indoor ventilation are well known but are often intentionally brought about as a simple way to reduce a building's energy consumption through improved air tightness. This has been seen in Scandinavian countries for many years due to the forward-looking building regulations in these countries that have brought about high air leakage standards. In the UK newly built houses are slowly evolving into more airtight structures and this has been dealt with by stipulating an open vent area to the outside for fresh air ingress. Too often the problem with this method however is that occupants are often unused to the concept of these intentional 'draughts' that they block or shut off these vents and then rely on often unhealthy background infiltration to fulfil their ventilation requirements. Also, the uncontrolled nature of these openings can cause highly variable air ingress rates often highly dependant on the external wind conditions, this can cause high energy penalties and draughts on cold windy days, and a lack of ventilation on warm days.

Another solution to this question of healthy ventilation and energy efficiency is the use of Mechanical Ventilation with Heat Recovery (MVHR) now popular in Scandinavia and becoming more so in temperate climates like the UK's (although the energy case for this is not clear). MVHR does however require a relatively high capitol cost injection that is likely to be beyond the capabilities of social housing providers, although fuel poverty and ill health disproportionately affects low-income families. There are also noise and maintenance considerations with these systems. It is therefore desirous to have a passive but controlled ventilation system that reduces the energy penalty associated with fresh air ingress.

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To this end funding from the European Unions 5th Framework Programme has been awarded to test the efficacy of a completely passive ventilation system called WHOLE-pvs, which includes PSV and window based heat reclaim, in three distinct climate bands within Europe. Social housing typical in each country were leased by the project with one dwelling designated as a test (new system) and control dwelling (typical system). After installation of the systems the houses are monitored without occupants to measure the performance of the supply air windows and the passive ventilation system. This will be followed by a period of occupied monitoring where the occupant interaction with the system will be gauged by the use of questionnaires and logbooks.

SYSTEM DESCRIPTION

The proposed system is an attempt to solve the often contradictory problems of energy efficiency and good indoor air quality. Studies (Norlen and Andersson, 1993) have shown the loss of indoor air quality often associated with air tight sealing of houses to reduce ventilation heat loss. To avoid this a passive system of ventilation PSV is coupled with pressure controlled vents, to regulate incoming ventilation levels, and supply air ventilated windows that reclaim heat and pre-heat the ventilation stream.

Supply air windows pre-heat the incoming ventilation stream by admitting outside air into the bottom of the window, which is allowed to rise up a ventilated cavity formed between the panes of glass, and then enters the building at the top of the window. When external temperatures are colder than internal this rising column of air picks up heat from the warmer internal pane and brings it back into the room reducing heat lost to the outside pane and pre-heating the incoming ventilation stream. This pre-heating can be increased by the exposure to solar radiation. Window *U*-values depend on their size, glazing configuration and ventilation rate through them but with a triple paned design with one low-E coating, a 1 m^2 area and a ventilation rate of 8 l/s *U*-values of 0.4 are achievable compared to 1.4 for an equivalent unventilated design. Night time ventilation pre-heat, as a function of the ventilation heat load, is usually in the region of 15–20%. Both assume an indoor/outdoor temperature of 20°C. In general, smaller windows will deliver lower *U*-values and ventilation pre-heat, as will higher ventilation flow rates. The windows in all houses are quite large ranging from 1.2 × 1.2 m to 1.5 × 1.5 m to 1.2 × 1.8 m and we therefore expect *U*-values above 0.4.

The design of the system has been refined through a UK funded research project (Baker and McEvoy, 1999; McEvoy and Southall, 1999, 2000) which addressed some of the problems encountered with previous designs such as reverse flow though the window with one-way valves, control of the airflow in a passively ventilated environment with pressure controlled trickle vents and optimization of the window configuration. This can result in controlled, passively generated ventilation into the building with a reduced energy penalty. The overall concept is shown in Figure 1.

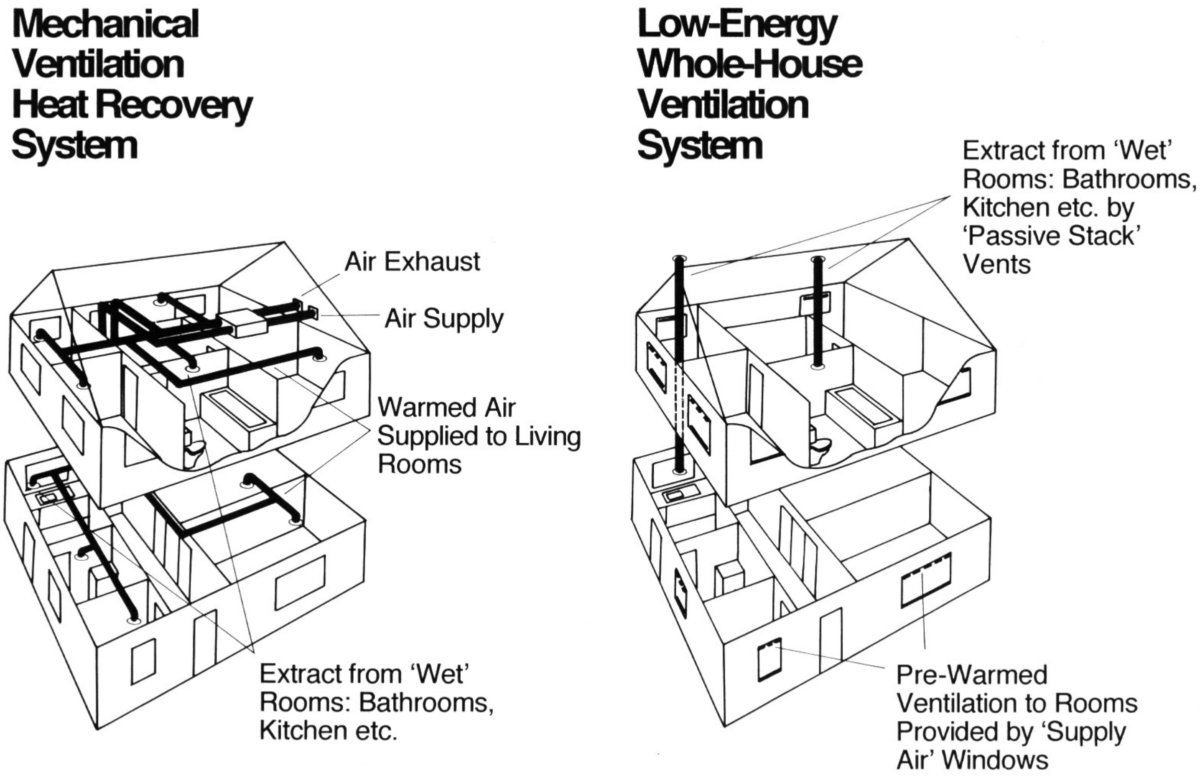

Figure 1 System concept.

PROJECT LOCATIONS AND BUILDINGS

Figure 2 shows the location of the three experimental sites in Armagh in Northern Ireland, Fredericia in Jutland, Denmark and Wroclaw in Poland. They typify the mild winter/summer of the maritime climate, the cold winters/mild summers of Scandinavia and the cold winters/hot summers of continental Europe.

Figure 2 Project locations.

In Ireland the houses are approximately 40 years old and are of concrete panel construction. They are two neighbouring two-storey mirror image houses within a terrace row, and subsequently have similar solar access. Windows are installed in the test house in the kitchen at the back of the house and a first floor bedroom also at the back. A PSV system is installed in the test house from the kitchen and the upstairs landing to the roof ridge. The control house was fitted with vent-axial fans in the kitchen and bathroom. Both houses required significant air tightening to bring them to the standard required for air to pass into the houses mainly through the windows.

In Denmark the new build houses are single storey and have identical plans. They are both situated within the same terrace row and thus again get equivalent solar access. Three windows are installed in the test house (two at the back facing south and one facing north) along with an improved PSV system incorporating a high wind catching terminal. The control house has a high efficiency MVHR system installed, as this is fast becoming a standard in Scandinavian countries. This has winter operation with heat reclaim and summer operation with air supply direct from outside.

In Poland the properties are new build single storey flats situated on the third floor of a four-storey block. Windows replace the only two windows in the test flat in the kitchen/bedroom space whilst the existing PSV system is kept as is. The control flat is left untouched with the existing PSV system and as is quite common in new build Polish flats with no specific air entrance point into the flat. Although the two flats neighbour each other and have the same window orientation (East) solar access is increased for the control flat due to shading from other parts of the building. Only minimal air tightening work was required due to the small and simple design of the flats.

MONITORING SET-UP

The monitoring of the houses is split into an unoccupied and occupied phases. For the occupied phase an extensive monitoring regime is set-up to gauge the performance of the windows and PSV ventilation. This includes weather stations at each site monitoring ambient temperature and humidity, wind speed and direction, solar radiation and rainfall. Internal monitoring includes heat flux mats positioned within the ventilated cavity of the windows measure the heat transfer to the outside and the window *U*-value, thermocouples to measure room and window cavity temperatures, anemometers to measure the air flow rates through the ventilation system, humitters to measure room humidity and solarimeters to measure incoming solar radiation. In addition each property has a sensor to monitor the heating energy supplied to the buildings.

For the unoccupied phase questionnaires will be given to the occupants to gauge their reaction to the system. They will also be given logbooks to mention any points relating to the performance of the system. During this unoccupied phase the heating input to the houses will be monitored, along with measurement of the internal temperature and humidity with tiny talk sensors. Airflow within the PSV system is also monitored if the sensors can be placed in the roof space away from the occupants.

SIMULATION TECHNIQUES

For the simulation of the building performance two simulation techniques have been employed. Computational Fluid Dynamics (CFD) (McEvoy and Southall, 2001) has been used to produce steady state analyses of the window *U*-values and thermal comfort within the dwellings. For the dynamic analysis ESP-r from the University of Strathclyde has been employed. Both have been shown to be able to model the window behaviour very well (McEvoy and Southall, 2002) and have been well validated in terms of general building energy and airflow modelling.

CFD modelling was used primarily to design the optimum configuration of the windows within the buildings, and to test their ability to deliver comfort conditions. Once this was confirmed the emphasis was placed on the dynamic ESP-r modelling which will be discussed briefly here.

ESP-r is a multi-zone thermal network model that can have associated networks (e.g. CFD, airflow) overlaid on top. Each zone within the network is isothermal and there is no spatial resolution available in the results within a zone. As the cavity within a ventilated window is of great importance to its performance and as this cavity is thermally stratified (both horizontally and vertically) a single zone approach to the cavity is not sufficient. Investigation has shown that eight zones within the ventilated cavity offer the best compromise between the performance and complexity of the model.

Initial models of the buildings used weather data generated by the Meteonorm climate database and this was used to predict energy usage and air flow rtes through the PSV ventilation systems. However initial results and monitored climate data have been generated by the project and can now validate these initial models.

STATE OF PROGRESS

The properties are currently being monitored for their energy performance and initial results are encouraging. Installation of the systems was straightforward and the cost was not significantly above that of standard windows and PSV system. It is hoped to be able to give initial results from the installations at the conference.

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