Comparing energy use and CO_2 emissions from natural ventilation and MVHR in a Passivhaus house

A CarbonLite Information Paper

January 2009

COMPARING ENERGY USE AND CO_2 EMISSIONS FROM NATURAL VENTILATION AND MVHR IN A PASSIVHAUS HOUSE

Two cases are explored – one using PHPP assumptions and one using SAP assumptions

EXECUTIVE SUMMARY

There is some debate as to whether MVHR (mechanical ventilation with heat recovery) is justified in the UK climate, or whether the energy used by the fans outweighs the heat saved.

This simple study takes a developer's 'standard-semi' house design of 83m², in Manchester, but with U-values specified to give a Passivhaus standard of heating demand of 15 kWh/m².a modelled in PHPP, and compares the energy use with and without MVHR.

The comparison is made for two sets of standardised internal heat gain assumptions – those from SAP and those used in PHPP. A third case makes more realistic assumptions about the natural ventilation rate.

Specific conclusions

i) MVHR does provide net carbon gains, if the system is efficient and well-designed and installed.

ii) The current level of internal gains assumed in SAP diminishes the apparent benefits of MVHR. This is because the gains appear to be meeting the fresh air heating load a fair amount of the time.

iii) As lighting appliances and hot water systems get more efficient, there will be less "free" heating and the benefits of MVHR will become clearer.

iv) The assumption in SAP of fixed levels of natural ventilation is idealistic; either heat losses are in fact higher than assumed, or at times ventilation levels are lower than assumed and there are consequent problems with condensation.

Introduction

1. There is some debate as to whether MVHR (mechanical ventilation with heat recovery) is justified in the UK climate, or whether the energy used by the fans outweighs the heat saved. There is a range of relevant factors – principally, fan efficiency, heating demand and ventilation rate. However, the choice of energy modelling assumptions also affects the argument.

2. This simple study takes a developer's 'standard-semi' house design of 83m², in Manchester, but with U-values[1] specified to give a Passivhaus standard of heating demand of 15 kWh/m².a modelled in PHPP[2], and compares the energy use with and without MVHR. The comparison is made for two sets of standardised internal heat gain assumptions – those from SAP and those used in PHPP. A third case makes more realistic assumptions about the natural ventilation rate.

3. Energy use is calculated by PHPP, which uses EN 13790 for calculating annual heating demand.

Case 1: using PHPP assumptions for internal gains

4. MVHR is calculated to operate for 4,900 hours per year based on the following assumptions:
   - a Passivhaus-standard MVHR unit is used
   - 87% installed efficiency (92% efficient unit with losses calculated in PHPP at 5%)
   - 0.36 W/m³.h electrical consumption

5. Internal gains are assumed to be the default figure used by PHPP at 2.1 W/m^2, a low figure by normal UK standards because PHPP assumes the best in domestic energy efficiency and also allows for negative factors such as evaporation.

Results

6. **With MVHR:** Assuming an average ventilation rate is 0.4 ac/h, (according to standard Passivhaus design[3]):
   - space heating energy demand is 1211 kWh, equating to 1346 kWh of gas[4], emitting 262 kg CO_2
   - MVHR electrical use is 146 kWh, resulting in CO_2 emissions of 80 kg (@ 0.55kg/kWh)
   - combined CO_2 emissions are 342 kg

7. **Without MVHR:** Assuming a natural ventilation rate of an average 0.5 ac/h (as specified in SAP):
   - the space heating energy demand is 3334 kWh, equating to 3704 kWh gas, emitting 722 kg CO_2

---

[1] The U-values used are similar to those used in CSH level 5 & 6 houses

[2] Passivhaus Planning Package

[3] Generally compliant with Part F of UK Building Regulations

[4] Allowing for standard gas boiler efficiency of 90%

8. Therefore, MVHR reduces heating CO_2 emissions by 460 kg in return for 80 kg caused by MVHR fan power, a 6:1 ratio, and a net saving of 380 kg CO2.

9. In addition, the following assumptions have also been made:

   a) no power consumption at all for ventilation in the natural ventilation case, even though such dwellings often have a few extract fans; and

   b) the natural ventilation is controlled adequately to achieve 0.5 ac/h average in varying wind and temperature conditions. In practice, such precise control of natural ventilation is practically impossible to arrange – adjusting for enough ventilation on a still day will tend to lead to over-ventilation on windy days.

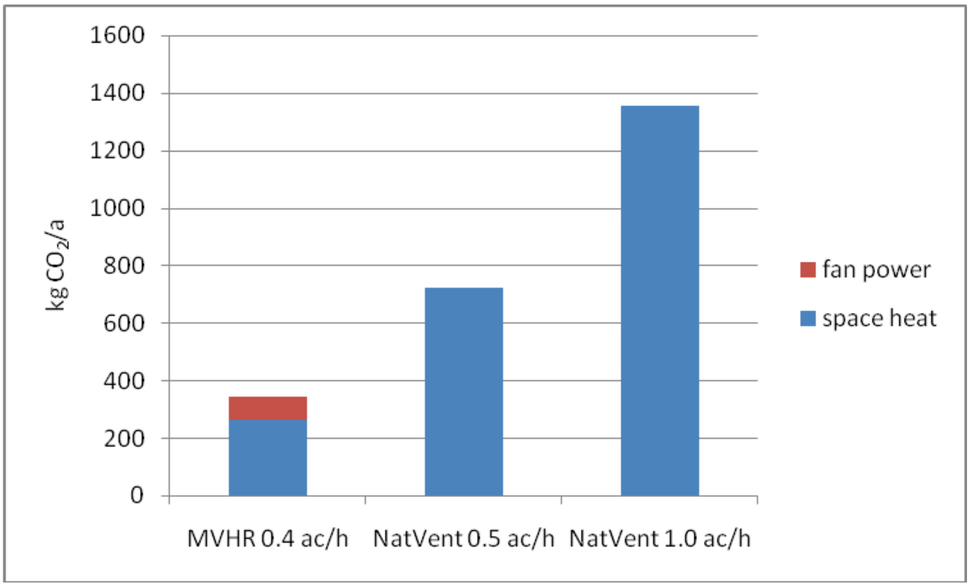
Case 3: Sensitivity to rate of natural ventilation

10. To determine the sensitivity to natural ventilation the figures were recalculated at an average ventilation rate of 1.0 ac/h.

11. This increased space heating energy demand to 6258 kWh, 6953 kWh gas, emitting 1356 kg CO_2. This represents a near doubling of the heating demand, demonstrating that control of ventilation heat loss is critical in well-insulated houses, and the control afforded by mechanical ventilation is therefore a significant consideration.

12. In this case therefore, MVHR reduces heating CO_2 emissions by 1356 kg CO2 in return for 80 kg caused by MVHR fan power, a 12:1 ratio, and a net saving of 1014 kg CO2.

Graph 1: using PHPP assumptions for internal gains



Case 2: using SAP assumptions for internal gains

13. The comparison was then carried out with the much higher internal gains assumed in SAP2005.

14. Here a figure of 7 W/m^2 was substituted for the default figure of 2.1 W/m^2 in PHPP. SAP internal gain figures are historic and have tended to assume reluctant progress towards energy efficiency – for example, any non-fixed lighting is assumed to be

tungsten, on the grounds that the builder can't prevent the occupant from replacing low energy lighting, appliances are energy-inefficient, and so on. Such assumptions are conservative in terms of electrical energy use but have an opposite effect on heating energy use, and hence thermal design.

Results

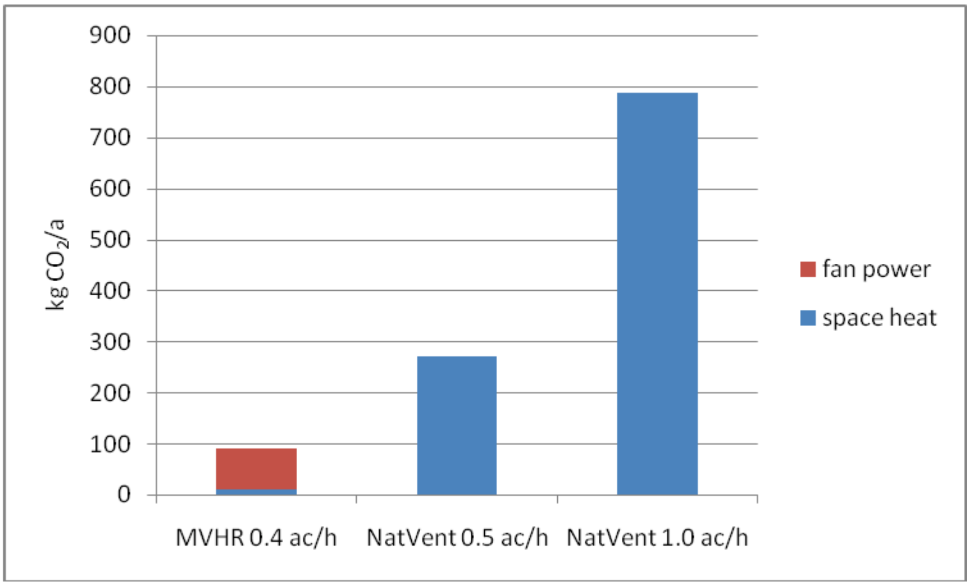
15. **With MVHR,** the space heating energy demand is 41 kWh per year, i.e. zero in practical terms. Were a gas boiler used, the CO_2 emissions would be 9kg. MVHR emissions are still 80kg, giving a total of 89kg.

16. **Without MVHR**, and assuming natural ventilation of an average 0.5 ac/h, the space heating energy demand is 1256 kWh, 1396 kWh gas, emitting 272 kg CO_2. (Interestingly, the assumed increase in internal gains brings the heat demand in the natural ventilation case down to 15 kWh/m².a, on a par with the Passivhaus standard).

17. So although the much higher internal gains assumed with SAP indicate much less heating is needed with natural ventilation, and practically none with MVHR, the carbon savings of adding MVHR would still be 183kg, and there is still a 3:1 carbon saving.

18. Again, considering the possibility of a higher ventilation rate of 1.0 ac/h with uncontrolled natural ventilation, the emissions would be 788kg CO_2 – practically a threefold increase.

Graph 2: using SAP assumptions for internal gains



Overall conclusions

19. In all cases, the total calculated CO_2 emissions from heating and MVHR combined was lower with MVHR than without, including with the SAP gains.

20. Some reasons for this are due to the use of PHPP; PHPP accurately models the system as designed, allowing for poor or good practice, whereas SAP assumes a worse case of poor installation design and practice thereby adding a big "safety margin". However, because there is no need to calculate the installed efficiency,

poor practice is more likely to be the norm and this safety margin will therefore appear justified.

21. PHPP permits lower ventilation rates to be set with MVHR whereas SAP assumes they will be the same as natural ventilation. In fact, this level of control is impossible with natural ventilation.

22. Some experience suggests that the opposite problem is starting to occur - reasonably airtight houses with natural ventilation are suffering condensation problems because their ventilation rates often fall too low (though presumably are higher when the wind blows).

Specific conclusions

v) MVHR does provide net carbon gains, if the system is efficient and well-designed and installed.

vi) The current level of internal gains assumed in SAP diminishes the apparent benefits of MVHR. This is because the gains appear to be meeting the fresh air heating load a fair amount of the time.

vii) As lighting appliances and hot water systems get more efficient, there will be less "free" heating and the benefits of MVHR will become clearer.

viii) The assumption in SAP of fixed levels of natural ventilation is idealistic; either heat losses are in fact higher than assumed, or at times ventilation levels are lower than assumed and there are consequent problems with condensation.

Table 1: **Results - Case 1: Using PHPP assumptions**

	Space heating demand (kWh)	Space heating gas use (kWh)	MVHR electricity use	Gas CO_2 emissions (kg CO_2)	MVHR CO_2 emissions (kg CO_2)	Total kg CO_2
With MVHR	1211	1346	146	262	80	342
Without MVHR (natural vent. of 0.5 ac/h)	3334	3704	-	722	-	722
Variance	**+2123**	**+2358**	**-146**	**+460**	**-80**	**+380**
Without MVHR ((natural vent. 1.0 ac/h)	6258	6953		1356	-	1356
Variance	**+5047**	**+5607**	**-146**	**+1094**	**-80**	**+1014**

Table 2: **Results - Case 2: Using SAP assumptions**

	Space heating demand (kWh)	Gas use (kWh)	MVHR electricity use	Gas CO_2 emissions (kg CO_2)	MVHR CO_2 emissions (kg CO_2)	Total kg CO_2
With MVHR	41	46	146	9	80	89
Without MVHR (natural vent. of 0.5 ac/h)	1256	1396	-	272	-	272
Variance	**+1215**	**+1350**	**-146**	**+263**	**-80**	**+183**
Without MVHR (natural vent. of 1.0 ac/h)	3637	4041	-	788	-	788
Variance	**+3596**		**-146**	**+779**	**-80**	**+699**

Table 3: Net saving in kg CO2 from the use of MVHR compared to natural ventilation

	Net saving ($kg\ CO_2$)
Using PHPP assumptions	
Without MVHR (natural vent. of 0.5 ac/h)	380
Without MVHR ((natural vent. 1.0 ac/h)	1014
Using SAP assumptions	
Without MVHR (natural vent. of 0.5 ac/h)	183
Without MVHR ((natural vent. 1.0 ac/h)	699