

**Volution Group plc**

## MVHR Emissions Savings

Emissions Assessment Calculator and Guidance

Reference: G01

1 | 12 September 2022

This report takes into account the particular instructions and requirements of our client. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 287565-00

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# 1. Introduction

This report has been prepared by Arup for Volution Group plc (“the Client”). It is part of a commission to assess the annual GHG emission savings potential from the use of Volution Mechanical Ventilation with Heat Recovery (MVHR) products. An MS Excel calculator has been developed to provide a sense of scale of the annual emission savings from the annual global MVHR product sales.

## 1.1 Project Overview

The aim of the project was to provide a method and an MS Excel calculator of the potential GHG emissions savings from the MVHR product sales worldwide.

Arup objectives through the stages of this commission were:

- To propose a method for the calculation of the potential GHG emissions in relation to the Client’s input sales data,
- To develop an MS Excel calculator based on the proposed method,
- To assess the sensitivity and error margins of the calculations and use the tool to create an interim report according to sales data in July 2022,
- To review and evaluate the method and tool and deliver a final version of the tool and a report in August 2022 based on the FY22 final sales data.

## 1.2 Issues discussed in this note

This report presents the calculator’s functions and provides guidance for its use. It outlines key steps and input requirements into the calculations, establishes the main assumptions, and discusses the results and their limitations.

## 2. Methodology

The baseline calculation assumes a single zone, detached building (domestic or commercial) with mechanical ventilation (MV). The total heat load of the model is a function of the fabric heat losses, heat losses due to infiltration (uncontrolled leakage) and heat losses due to ventilation. The heat losses due to fabric and infiltration remain the same across the baseline (MV without heat recovery) and the MVHR case. The energy and consequently GHG emissions reductions are due to the change in MV heat losses.

The tool uses hourly average air temperature data from [Climate.OneBuilding.Org](#) [1] to estimate the hourly average temperature differences between outdoor and room temperature. It calculates the degree days for a specific base temp (i.e. room heating setpoint and setback temperatures) from hourly average ambient temperatures. The degree days are dynamically calculated for each product entry in the ‘Weather stats’ according to the country of sales indicated each time. An extensive list of countries and weather data has been provided with the tool according to the final sales data provided in August 2022. The capital city of each country has been selected as the location for regional weather data source. The countries are reported with the international 3 letter code identifier. The tool does not differentiate between climatic zones within countries.

The MVHR case calculates the supply air (air heated by the heat exchanger) temperature based on the heat recovery efficiency of the selected product. In the next step, the temperature difference between the supply temperature and the room temperature is estimated and used in the calculation of the heat losses due to ventilation.

Then the heat losses due to fabric and infiltration are added to the final heat load and the heating requirements are estimated. Primary energy and GHG emissions are calculated based on the heating system efficiency and the emissions factors for mains gas and grid electricity. The emission factors can be updated for each country. This could also provide a case study for the emission avoidance forecast assuming the increase in use of electric heating systems and lower emission factors for grid electricity.

The method is following guidance from CIBSE Guide B [2] and the SAP2012 methodology with the main difference being the calculation of ventilation losses using the MV reference air flow rates provided by the Client.

In a final step, the sales and the results from the ‘Interface’ are used to estimate and showcase the total emission avoidance per product and region in the ‘Dashboard’ page.

### 2.1 Structure of the calculator

The calculation and the MS Excel calculator adopt a streamlined approach that allows customisation and further development. The amount of input is minimised, and the results can be shown in a Dashboard.

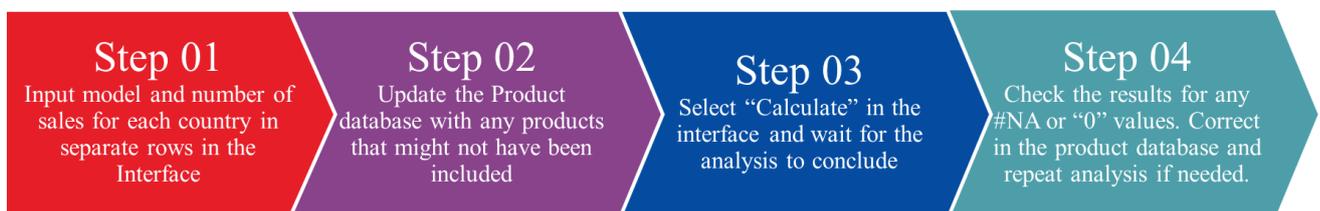


Figure 1. Emissions avoidance calculation steps.

### 3. Main assumptions

There are a large number of assumptions due to the uncertainties with the actual conditions of use of the products. The main assumptions are:

- A. The calculations for the domestic application consider that mechanical ventilation and heating is ON all year round, 365 days and 24 hours a day. There is no alternative schedule for the weekends. The heating requirement is controlled by the thermostat. The room setpoint temperature is assumed to be 21°C. The room set-point temperature can be changed by the user.
- B. The commercial application assumes that the ventilation and heating system operate continuously for 14 hours a day (05:00 to 19:00) at a 21°C room setpoint temperature and the rest of the time the system operates at a setback temperature of 12°C. This schedule was based on the NCM activity Database (2022), available at <https://www.uk-ncm.org.uk/>. The setpoint and setback temperatures can be changed in 'Model Parameters' in the tool.
- C. The building is modelled as one thermal zone. The calculation is steady state.
- D. The domestic application baseline assumes heating with a gas boiler. The fuel is mains gas. The boiler efficiency is user adjustable (default is 89.5%).
- E. The commercial application baseline assumes the existence of a heating and ventilation system with a heating coefficient of performance (COP) of 3 (i.e. 300% heating efficiency).
- F. The domestic building parameters are described by the Notional Dwelling (SAP2012 - Appendix R, Table R1, Part L1A) in the UK [3]. U-values of the fabric, infiltration and ventilation rates can be adjusted by the users.
- G. The commercial building parameters are described by the Notional Building – Part L2A (Table 5, pp.27) [4].
- H. The emission factors for mains gas and grid electricity for each country come from various sources as listed in 'Model Parameters'. Grid electricity emissions factor for Europe and Australasia are mainly based on the database listed in [5]. The values can be adjusted by the user.
- I. The MVHR units are balanced systems. In the baseline case, the extract mass flow rate is considered equal to fresh air mass flow rate through infiltration.
- J. The MVHR units are all assumed to have a fresh air bypass that is used for the inflow when there is no heating demand (i.e. outdoor temperature higher than room heating setpoint).
- K. The MVHR units are considered to have a counter-flow/crossflow heat exchanger and a panel filter. The default pressure drop for a system with two flows and one supply air filter is assumed to be 230 Pa [6].
- L. Internal gains have not been included in the calculations. Indicative gains from occupancy and equipment are shown in the 'Residential' and 'Non-residential' inputs and could be added in future.
- M. The thermal capacity of building elements and the thermal inertia of the building have not been considered in the calculations.
- N. Heat losses due to infiltration have not been adjusted for the effect of wind speeds. There is an option to adjust the heat loss due to infiltration for the number of sheltered building sides.
- O. The domestic application has been modelled for a detached dwelling. The commercial application has been modelled for an open-plan office building. Both buildings are assumed to have 100m<sup>2</sup> floor area as default. Floor area can be adjusted by the user.

## 4. Calculator user guide

The MS Excel calculator comprises 3 distinct parts:

1. The product and weather database,
2. The calculations of energy and savings,
3. The output interface and a dashboard with the key results.

### 4.1 Product and weather database

The product and weather databases allow users to add products, edit their specifications and edit the climate zones/regions according to regional sales. Minimum input data requirements and the format were discussed and decided through the update meetings with the Client. The current version of the tool has been used to analyse the FY22 sales data provided in August 2022. Many countries and the relevant weather data have been added to the weather dataset of the tool to facilitate the Client to report all sales world-wide. The current version of the tool includes 39 countries. Appendix 2 provides instructions on adding further weather data.

The main 'Interface' tab is shown below.

Calculate	Model	GBR	BEL	FRA	DEU	NLD	DNK	FIN	SWE	ALA	EST	NOR	NZL	ITA	ESP	CHL	AUS	HUN	ROU	UKR	LTU	SRB	SVK	TUR	RUS	PRT	POL	LVA	GRC	BGR	HRV	CZE	
	ACCU-2543-1990-3020-07-96-420-T-S-1-420V																1																
	PCF-110-1215																3																
	PCF-110-900																4																
	PCF-110-932-B-118-B																5																

Figure 2. The main interface for entering the product and sales per country.

The 'Interface' requires the product model with the number of total sales per country added to the relevant country column. Multiple models and sales of the same model in the same country can be entered in the interface separately. However, there must always be only one country's sales reported in each row. For example, the calculator will work correctly in the case of Model X with 4 sales in the UK in a row and Model X with another 6 sales in the Belgium in a different row. The calculator will not work correctly if Model Y with 8 sales in Germany and 10 sales in France are reported in the same row simultaneously. This data should be split into two separate entries. An example of correct and erroneous data entry is shown in below.

#### Correct data entry

Calculate	Model	GBR	BEL	FRA	DEU	NLD	DNK	FIN	SWE
	PCF-110-1215		2						
	PCF-110-1215			3					
	PCF-110-900		2						
	PCF-110-932-B-118-B					5			

**Erroneous data entry**

<div style="border: 2px solid green; padding: 5px; display: inline-block;">Calculate</div>	<b>Model</b>	<b>GBR</b>	<b>BEL</b>	<b>FRA</b>	<b>DEU</b>	<b>NLD</b>	<b>DNK</b>	<b>FIN</b>	<b>SWE</b>
	PCF-110-1215		2	3					
	PCF-110-900		2		6	9			
	PCF-110-932-B-118-B					5			

The ‘Product database’ needs to be pre-populated with the products listed in the ‘Interface’. If a product is not listed in the ‘Product database’, the calculation will carry on but the values in the results will show a #N/A value. In that case, the product specifications should be added into the ‘Product database’ sheet and the results should be recalculated.

The product specifications needed for the calculations are:

- Model name (Important: This should match the model’s name in the ‘Interface’)
- Reference flow rate (in m<sup>3</sup>/s)
- Heat recovery efficiency as %, for example 90 for 90% efficiency (not 0.9)
- Application (Domestic or Commercial selection from drop down list)
- The electricity use of the unit in the form of Annual Electricity Consumption (AEC) in kWh/m<sup>2</sup> for domestic products or in the form of Effective Elec. Power input in kW for commercial units.

The ‘Product database’ tab is shown below.

Type	Model	Ref Flow rate (m <sup>3</sup> /s)	Heat recovery		Application	AEC (kWh/m <sup>2</sup> )	Effec elec. Power input (kW)
			Thermal Efficiency (%)				
	ACCU-2543-1930-1610-07-PL-A20-T-S-1-400V		4.7		90 Commercial		1.3
	PCF-110-1070		1.6		87 Commercial		0.4
	PCF-110-1200		1.8		87 Commercial		0.5

**Figure 3. Example product database table and the product specifications required.**

The current version of the tool has been provided with all the products listed in the Client sales data for FY22.

**Commercial products**

The Effective Electric Power input for commercial products without any relevant data has been calculated with the equation [1]:

$$P = Q * \Delta p / n_{fan}$$

Where P is Power (W), Q is the airflow (m<sup>3</sup>/s), Δp is the pressure drop through the system (assumed 230 Pa) and n<sub>fan</sub> the total efficiency of the fan, drive and system (assumed 0.85).

**4.2 Main calculations**

The ‘Inputs’ and ‘Calculations’ sheets contain the baseline cases, parameters used in the calculations, key assumptions, and step-by-step calculations.

The calculator uses a macro to iterate through the rows in the ‘Interface’. For each iteration, the GHG emissions reduction is calculated in the ‘SelectedProduct’ sheet. This is the main calculation module, and the calculations can be easily interrogated. If these calculations are altered, then the user should simply re-run the calculation from the ‘Interface’ to apply the changes and produce new results for all sales data.

The calculator allows the user to update the baseline and change the properties of buildings and systems according to future building regulations or “typical” building characteristics in each country.

### **4.3 Output and reporting**

The calculations are streamlined, and the results are shown in the ‘Interface’ sheet when the analysis is completed. Results are aggregated and populate the ‘Dashboard\_Data’ sheet. This is used to visualise key findings in the ‘Dashboard’ with graphs and data that can be used for reporting.

## 5. Conclusion

It is expected that this simple calculation tool delivers results with an acceptable accuracy in the scope of this project. The model calculates as default the GHG emissions avoided with the use of MVHR in domestic and commercial buildings against a baseline case of a building without heat recovery and a heating system that operates continuously (domestic case) or during 14 hours from 05:00 to 19:00 daily in the commercial case (and at a setback temperature the rest of time).

The avoided GHG emissions would be lower than reported if different heating and occupancy schedules with fewer hours and days of heating were considered (e.g. 10 hrs heating per day only for the period from September to April). The results should be considered as an upper limit estimation of emissions avoidance. The uncertainty remains high as the Client does not have access to data about the use of the systems in the buildings or the installation conditions and operation after the sale of the products.

Given the uncertainties, the Client should consider using the tool to report relative percentage changes in energy usage and GHG emissions and not for the quotation of absolute numbers.

It should be noted that extrapolating GHG reductions over the product lifetime is complex due to changing grid emissions factors. These results should only be used to report savings in the year of sale.

## 6. Next steps

The reporting process and use of the tool would benefit from standardisation of the product names and format. A global online database of the products, their specifications and annual sales could help to streamline analytics and the reporting process.

## 7. References

1. Climate.One.Building.Org. (2022, April). *Repository of free climate data for building performance simulations*. <https://www.climate.onebuilding.org/>.
2. Chartered Institution of Building Services Engineers. (2016). *Ventilation and ductwork : CIBSE guide B2 : 2016*.
3. BRE. (2013). SAP 2012 The Governments Standard Assessment Procedure for Energy Rating of Dwellings 2012 edition. [www.bre.co.uk/sap2012](http://www.bre.co.uk/sap2012)
4. UK Building Regulations 2010, Conservation of fuel and power, Notional Building – Part L2A (Table 5, pp.27).
5. Country specific electricity grid greenhouse gas emission factors. Available at: <https://ourworldindata.org/grapher/carbon-intensity-electricity?tab=table>
6. Dwyer, T. (2013). Module 49: Saving energy through simple HVAC heat recovery. *CIBSE Journal*. <https://www.cibsejournal.com/cpd/modules/2013-02/>

## 8. Appendix 1

### 8.1 Calculation Steps – Domestic units

The main calculations take place in the ‘Selected Product’ and the ‘Weather Stats’ sheets.

1. The heat loss rate due to ventilation (heat loss coefficient) (W/K)  $P_v$  is calculated in Column AM in the ‘Selected Product’ sheet according to the reference flow rate  $q_v$  (m<sup>3</sup>/s) of the product from equation (A1):

$$P_v(W/K) = C_p \times p \times q_v \times 1000 = 1.01 (kJ/kgK) \times 1.2 (kg/m^3) \times q_v (m^3/s) \times 1000$$

(Eq. A1)

Where  $C_p$  is the specific heat capacity of air (1.01 kJ kg<sup>-1</sup>K<sup>-1</sup>) and  $p$  is the density of air (1.2 kg/m<sup>3</sup>). The result is multiplied by 1000 to convert kW into W.

2. The heat loss rate (W/K)  $P_b$  through conduction and infiltration (Column AN in “Selected Product” sheet) is used as a constant. The calculation is based on the SAP methodology, and it uses the building characteristics as detailed in the ‘Residential’ sheet.
3. The air mass flow rate (kg/s<sup>-1</sup>) (Column AO in ‘Selected Product’) is determined by the ventilation reference flow rate  $q_v$  (m<sup>3</sup>/s) divided by the specific volume of air (0.83 m<sup>3</sup>/kg<sup>-1</sup>). The air mass flow rate is used only in the commercial units’ calculations.
4. The temperature  $t_R$  of the outdoor air leaving the heat exchanger (pre-heated fresh air) is

$$t_R = t_{out} + n_{HR} \times (t_{in} - t_{out}) \quad (\text{Eq. A2})$$

Where  $n_{HR}$  is the heat recovery efficiency of the heat exchanger (“Product Database” sheet).

5. The tool looks into the input sales and finds for each entry row (in ‘Interface’ sheet) the total number of sales and the region of sales (Columns AH and AI in ‘Selected Product’). In the ‘Weather Stats’ sheet, the weather data for the region are used to estimate the temperature difference ( $\Delta T$ ) for the heating energy demand. The baseline case is mechanical ventilation without heat recovery. In the domestic case,  $\Delta T = t_{in} - t_{out}$  where  $t_{in}$  is the room set-point temperature (°C). In the MVHR case  $\Delta T_{MVHR} = t_{in} - t_R$ .
6. For the domestic units, heating is always available based on the room set point temperature.
7. The average daily temperature difference is multiplied by the number of days in each month, to calculate the average degree days for a year.
8. The heating energy demand is calculated according to the equation for the baseline case (Eq. A3):

$$H(kWh) = (P_v + P_b) (W/K) \times \Delta T \times 24h / 1000 \quad (\text{Eq. A3})$$

where  $P_v$  is the heat loss rate from ventilation and  $P_b$  the constant heat loss rate from conduction and infiltration.

9. In the MVHR case, the heating energy demand is calculated by (Eq. A4):

$$H(kWh) = ((P_v \times \Delta T_{MVHR}) + (P_b \times \Delta T)) \times 24h / 1000 \quad (\text{Eq. A4})$$

10. The electricity requirement for domestic MVHR units is calculated and added to the calculation of the final GHG emissions avoidance estimation (Column AU in 'Selected Product'). The electricity demand for MVHR is estimated by the AEC (kWh/m<sup>2</sup>) specifications in the 'Product Database'.
11. The emissions avoidance is the difference in emissions from the heating energy use between the baseline and the MVHR case with the addition of the emissions from the ventilation units' electricity use. The emission factors are in the 'Model Parameters' sheet. The total emissions multiply the number of units sold (Column AH) with the final emissions avoidance result (Column AU).
12. The calculation steps are repeated for each entry (row) and the results are copied back to the 'Interface'.

## 8.2 Calculation Steps – Commercial units

The main calculations take place in the ‘Selected Product’ and the ‘Weather Stats’ sheets.

1. The heat loss rate due to ventilation (heat loss coefficient) (W/K)  $P_v$  is calculated in Column AM in the ‘Selected Product’ sheet according to the reference flow rate  $q_v$  (m<sup>3</sup>/s) of the product from equation (B1):

$$P_v(W/K) = C_p \times p \times q_v \times 1000 = 1.01 (kJ/kgK) \times 1.2 (kg/m^3) \times q_v(m^3/s) \times 1000$$

(Eq. B1)

where  $C_p$  is the specific heat capacity of air (1.01 kJ kg<sup>-1</sup>K<sup>-1</sup>) and  $p$  is the density of air (1.2 kg/m<sup>3</sup>). The result is multiplied by 1000 to convert kW into W.

2. The heat loss rate (W/K)  $P_b$  through conduction and infiltration (Column AN in “Selected Product” sheet) is used as a constant. The calculation is based on the SAP methodology, and it is based on the building characteristics as detailed in the ‘Non-Residential’ sheets in the tool.
3. The air mass flow rate (kg/s<sup>-1</sup>) (Column AO in ‘Selected Product’) is determined by the ventilation flow rate  $q_v$  (m<sup>3</sup>/s) divided by the specific volume of air (0.83 m<sup>3</sup>/kg<sup>-1</sup>). The air mass flow rate is used to estimate the required supply air temperature ( $t_s$ ) from ventilation heating based on the conductive heat losses and the room set point temperature. This calculation applies to commercial products only. The supply air temperature is the temperature that the air from the MVHR unit should reach to achieve the room set point temperature. It is an indication of the heat requirement due to the mass flow rate. This can be achieved for example with a heating coil in larger HVAC systems. The calculation is based on the equation:

$$P_b \times (t_{in} - t_{out}) = \dot{m} (kg/s) \times C_p \times (t_s - t_{in}) \quad (\text{Eq. B2})$$

where  $\dot{m}$  (kg/s) is the mass flowrate calculated by the reference ventilation flow rate and  $C_p$  is the specific heat capacity of air (1.01 kJ kg<sup>-1</sup>K<sup>-1</sup>).

4. The temperature  $t_R$  of the outdoor air leaving the heat exchanger (pre-heated fresh air) is

$$t_R = t_{out} + n_{HR} \times (t_{in} - t_{out}) \quad (\text{Eq. B3})$$

where  $n_{HR}$  is the heat recovery efficiency of the heat exchanger. The air temperature after the heat exchanger is calculated according to the set point and setback room temperature.

5. The tool looks at the input sales and finds for each entry row (in ‘Interface’ sheet) the total number of sales and the region of sales (Columns AH and AI in ‘Selected Product’). In the sheet ‘Weather Stats’ the weather data for the region are used to estimate the temperature difference ( $\Delta T$ ) for the heating energy demand. The baseline case is mechanical ventilation without heat recovery. In the commercial case,  $\Delta T = t_s - t_{out}$  where  $t_s$  is the air supply temperature.

6. For commercial MVHR systems, the temperature difference is then calculated as  $\Delta T_{MVHR} = t_s - t_R$ . The heating is based on the set point temperature during the working hours and on the setback temperature during out of occupancy hours (see Section 3, Assumption B).
7. The average daily temperature difference is multiplied by the number of days in each month, so that the average degree days for the year are calculated.
8. The heating energy demand is calculated according to the equation for the baseline and MVHR case (Eq. B4):

$$H(kWh) = (P_v + P_b) (W/K) \times \Delta T \times 24h/1000 \quad (\text{Eq. B4})$$

where  $P_v$  is the heat loss rate from ventilation and  $P_b$  the constant heat loss rate from conduction and infiltration.

9. In the MVHR case the heating energy demand is calculated with (Eq. B5):

$$H(kWh) = (P_v + P_b) (W/K) \times \Delta T_{MVHR} \times 24h/1000 \quad (\text{Eq. B5})$$

10. The electricity demand for MVHR is estimated from the Effective Electric Power in the 'Product Database'. If the Effective Electric Power is not available, it can usually be calculated with the power equation shown in Section 4.1.
11. The emissions avoidance is the difference in emissions from the heating energy use between the baseline and the MVHR case with the addition of the emissions from the ventilation units' electricity use. The emission factors are in the 'Model Parameters' sheet. The total emissions multiply the number of units sold (Column AH) with the final emissions avoidance result (Column AU).
12. The calculation steps are repeated for each entry (row) and the results are copied back to the 'Interface'.

## 9. Appendix 2

### 9.1 Current list of locations

<b>Code</b>	<b>Country Name</b>
ALA	Finland - Jomala, Aland
ARE	United Arab Emirates
ARM	Armenia
AUT	Austria
BEL	Belgium
BGR	Bulgaria
CAN	Canada
CHE	Switzerland
CHL	Chile
CZE	Czech Republic
DEU	Germany
DNK	Denmark
ESP	Spain
EST	Estonia
FIN	Finland
FRA	France
GBR	United Kingdom
GRC	Greece
HRV	Croatia
HUN	Hungary
IRL	Ireland
ITA	Italy
LTU	Lithuania
LVA	Latvia
MKD	Macedonia
NLD	Netherlands
NOR	Norway
NZL	New Zealand
POL	Poland
PRT	Portugal
ROU	Romania
RUS	Russia
SRB	Serbia
SVK	Slovakia
SVN	Slovenia
SWE	Sweden
TUR	Türkiye
UKR	Ukraine
USA	United States of America

## 9.2 Adding additional weather data

Weather data for 39 locations is currently included in the tool. Additional locations can be added by following these steps:

1. Search for the location at [Climate.OneBuilding.Org](https://climate.onebuilding.org) [1] and download the file named '[LOCATION]\_TMYx.2007-2021.zip'.
2. Extract the .stat file from the zip folder and open it in Notepad.
3. Copy the filename into 'Weather stats' > Column A
4. Copy the 'Average Hourly Statistics for Dry Bulb temperatures [C]' table into 'Weather stats' > Column A and add a unique 3-letter code alongside in Column A. This is usually the ISO country code but can be user-defined.
5. Add the new location to the bottom of the countries table in 'Model Parameters', ensuring the 3-letter code matches the table in 'Weather stats'.
6. Find the emissions factor for the location (database listed in [5]) and add to the countries table in 'Model Parameters'.
7. Insert an additional column to the table in 'Interface' and use the 3-letter code as the column header.

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