INSTITUTO SUPERIOR DE ENGENHARIA DO PORTO

MESTRADO EM ENERGIAS SUSTENTÁVEIS

ANALYSIS OF SPECIFIC ENERGY CONSUMPTION FOR RESIDENTIAL VENTILATION UNITS ACCORDING TO THE EUROPEAN STANDARDS

SANJEETH PALANISAMY

Julho de 2018

POLITÉCNICO
DO PORTO

Title of Master's Thesis on Sustainable Energies

Analysis of Specific Energy Consumption for Residential Ventilation Units according to the European Standards

Dissertation submitted to obtain the degree of

Master in Sustainable Energy

Instituto Superior de Engenharia do Porto

Department of Mechanical Engineering

6 de julho de 2018

Report of the Dissertation for the

MSc in Sustainable Energy

Candidato: Sanjeeth Palanisamy, Nº 1150335, 1150335@isep.ipp.pt

Scientific Orientation: Olga dos Remédios Sobral Castro, orc@isep.ipp.pt

Scientific Coordination: Olga dos Remédios Sobral Castro, orc@isep.ipp.pt

MSc in Sustainable Energy

Department of Mechanical Engineering

isep Instituto Superior de Engenharia do Porto

6 de julho de 2018

“To succeed in your mission, you must have single-minded devotion to your goal”

--Dr. APJ Abdul Kalam

Acknowledgements

I would first like to thank my thesis advisor Olga dos Remédios Sobral Castro at Instituto Superior de Engenharia do Porto. The door to her office was always open whenever I ran into a trouble spot or had a question about my research or writing. She consistently allowed this paper to be my own work, but steered me in the right direction whenever she thought I needed it.

I would like to acknowledge Nídia Caetano the Course Co Ordinator of Sustainable Energy at Isep for her ideas and guidance in allowing me to choose this title for my master dissertation.

Finally, I must express my very profound gratitude to my parents for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

Resumo

Esta tese destaca a importância das Unidades de Ventilação Residenciais na atividade diária, e também, destaca o sistema de etiquetagem das unidades de ventilação residenciais. A ventilação residencial é uma das partes importantes num edifício residencial eficiente do ponto de vista energético e ambiental, pois elimina a humidade, a condensação nas superfícies e o crescimento de fungos dentro da estrutura do edifício. À medida que mais edifícios são construídos sobre o novo conceito de consumo de energia zero, que são edifícios ecologicamente corretos e que atendem aos padrões da ASHRAE para ventilação, torna-se importante para dar resposta para este tipo de construção, instalar Unidades de Ventilação Residencial com recuperação de calor. Muitos dos países europeus transitaram do método de ventilação natural para outros métodos de ventilação nos últimos anos, mas ainda há espaço para o crescimento de unidades de ventilação com a instalação de trocadores de calor.

Esta tese abrange principalmente as Unidades de Ventilação Residencial que foram avaliadas no âmbito do "REGULAMENTO DELEGADO (UE) N.o 1254/2014". Além disso, abrange o cálculo de vários parâmetros, como Consumo Específico de Energia (SEC), Aquecimento Anual Poupado (AHS), Consumo Anual de Energia (AEC), Potência Específica Consumida (SPI) e nível de potência sonora de diferentes fabricantes em todo o mundo.

Os parâmetros obtidos foram analisados e comparados entre os vários fabricantes, e foi verificado que o valor de SEC do melhor caso é 1,8 vezes menor do que o pior caso. Comparando os resultados com os aquecedores convencionais, há uma redução média de 30% relativamente ao consumo destes últimos. Substituir o tipo convencional é aconselhável, para que o impacto desses aquecedores convencionais no ambiente possa ser reduzido, pois eles usam uma enorme quantidade de combustível e eletricidade para sua operação.

Palavras-Chave

Poupança anual de energia para aquecimento ambiente, Consumo de eletricidade anual, Unidade de ventilação residencial, Potência específica consumida, Energia específica consumida.

Abstract

This thesis highlights the importance of the Residential Ventilation Units and its significance in daily activity. It highlights the labelling system of the Residential Ventilation units. Residential Ventilation is the most important part in a energy efficient residential building. It eliminates the moisture, surface condensation and mould growth inside the structure. As more buildings are been constructed on the new zero energy consumption, which are eco-friendly buildings and the old buildings which are not zero energy, does not meet the ASHRAE standards for ventilation. The key answer for this kind of building is to install a Residential Ventilation Unit with heat recovery. Many of the European countries transitioned from natural ventilation method to other ventilation methods in recent years, but there is still space for the growth of ventilation units with heat exchangers installation.

This thesis mainly covers Residential Ventilation Units which are been assessed under the "COMMISSION DELEGATED REGULATION (EU) No 1254/2014". Also, it covers the calculation of various parameters such as Specific Energy Consumption (SEC), Annual Heating Saved (AHS), Annual Energy Consumption (AEC), Specific Power Input (SPI) and sound power level of different manufacturers around the world.

The recent changes in the above-mentioned directive have brought a significant change in the labelling system of the Residential Ventilation Units which brings the system towards a more sustainable and economical path. The obtained parameters were analysed and compared within the manufacturers and found that the SEC value of the best case is 1.8 times lower than the worst case. Comparing the results with the conventional heaters, there is an average of 30% less energy consumption by RVU. Replacing conventional type is advisable, so that the impact of those conventional space heaters to the environment can be reduced as they use an enormous amount of fuel and electricity for their operation.

Keywords

Annual Heating Saved, Annual Electricity Consumption, Residential Ventilation Units, Specific Power Input, Specific Energy Consumption.

Declaration

Sanjeeth Palanisamy declares, under a commitment of honour, that this work is original and that all non-original contributions were duly referenced, with identification of the source.

6 de julho de 2018

Signature

Index

Index of Figures

Index of Tables

Nomenclature

AEC	–	Annual Electricity Consumption (electric power per year)	($kWha^{-1}$)
AHS	–	Annual Heating Saved (fuel gross calorific value per year)	($kWha^{-1}$)
$Cair$	–	Specific heat capacity of air at constant pressure and density	($kWhm^{-3}K^{-1}$)
$CTRL$	–	Ventilation control factor	
$MISC$	–	Aggregated general typology factor	
Pef	–	Primary energy factor for electric power generation and distribution	
Q_{defr}	–	Annual heating energy per m^2 heated floor area for defrosting, based on a variable electric resistance heating	
q_{net}	–	Net ventilation rate demand per m^2 heated floor area	($m^3h^{-1}m^{-2}$)
q_{ref}	–	Reference natural ventilation rate per m^2 heated floor area	($m^3h^{-1}m^{-2}$)
SEC	–	Specific Energy Consumption	($kWhm^{-2}a^{-1}$)
SPI	–	Specific Power Input	($Kwm^{-3}h^{-1}$)
t_a	–	Annual operating hours	(ha^{-1})
t_{defr}	–	Duration of the defrosting period, i.e. when outdoor temperature is below -4'c	(ha^{-1})
t_h	–	Total heating hours	(h)

X – Exponent that takes into account non-linearity between thermal energy and electric saving, depending on motor and drive characteristics

ΔT_{defr} – Average difference in K between the outdoor temperature and -4’c during defrosting period

Δt_h – Average difference in indoor and outdoor temperature (K) over a heating season, -3 K correction for solar and internal gains

η_h – Average space heating efficiency

η_t – Thermal efficiency of heat recovery

Abbreviations

AI – *All Inclusive*

AEC – *Annual Electricity Consumption*

AHS – *Annual Heating Saved*

ASHRAE – *American Society of Heating, Refrigeration and Air-conditioning Engineering*

BVU – *Bidirectional Ventilation Unit*

HRS – *Heat Recovery System*

HRV – *Heat Recovery Ventilation*

MSD – *Multi-Speed Drive*

MVHR – *Mechanical Ventilation Heat Recovery*

NRVU – *Non-Residential Ventilation Unit*

REHVA – *Federation of European Heating, Ventilation and Air-Conditioning Association*

RVU – *Residential Ventilation Unit*

SEC – *Specific Energy Consumption*

SPI – *Specific Power Input*

UVU – *Unidirectional Ventilation Unit*

VSD – *Variable Speed Drive*

VU – *Ventilation Unit*

Glossary of terms

BVU	–	*Ventilation unit producing an air flow between indoors and outdoors and which is equipped with both exhaust and supply fans.*
Central demand control	–	*A demand control of a ducted ventilation unit that continuously regulates the fan speed(s) and flow rate based on one sensor for the whole ventilated building or part of the building at central level.*
Clock control	–	*A clocked (daytime-controlled) human interface to control the fan speed/flow rate of the ventilation unit, with at least seven weekday manual settings of the adjustable flow rate for at least two setback periods, i.e. periods in which a reduced or no flow rate applies.*
Control factor (CTRL)	–	*A correction factor for the SEC calculation depending on the type of control that is part of the ventilation unit.*
Demand control	–	*A device or set of devices, integrated or as a separate delivery, that measures a control parameter and uses the result to regulate automatically the flow rate of the unit and/or the flow rates of the ducts.*
Demand controlled ventilaiton	–	*A ventilation unit that uses demand control.*
Ducted unit	–	*A ventilation unit intended to ventilate one or more rooms or enclosed space in a building through the use of air ducts, intended to be equipped with duct connections.*
Effective power input	–	*electric power input at reference flow rate and corresponding external total pressure difference and includes the electrical demand for fans, controls (including remote controls) and the heat pump (if integrated).*

HRS – *Part of a BVU equipped with a heat exchanger designed to transfer the heat contained in the (contaminated)exhaust air to the (fresh)supply air.*

Local demand control – *A demand control for a ventilation unit that continuously regulates the fan speed(s) and flow rates based on more than one sensor for a ducted ventilation unit or one sensor for a non-ducted unit.*

Manual control – *Any control type that does not use demand control.*

Maximum flow rate – *Maximum air volume flow rate of a ventilation unit that can be achieved with integrated or separately co-supplied controls at standard air conditions (20'c and 101 325 Pa).*

Multi speed drive – *Fan motor that can be operated at three or more fixed speeds plus zero (off).*

Non-ducted unit – *A single room ventilation unit intended to ventilate a single room or enclosed space in a building, and not intended to be equipped with duct connections.*

Recuperative heat exchanger – *A heat exchanger intended to transfer thermal energy from one air stream to another without moving parts, such as a plate or tubular heat exchanger with parallel flow, cross flow or counter flow, or a combination of these, or a plate or tubular heat exchanger with vapour diffusion.*

Regenerative heat exchanger – *A rotary heat exchanger incorporating a rotating wheel for the purpose of transferring thermal energy from one air stream to the other, including material allowing latent heat transfer, a drive mechanism, a casing or frame, and seals to reduce bypassing and leakage of air from one stream or another; such heat exchangers have varying degrees of moisture recovery depending on the material used.*

RVU	–	*Ventilation unit where maximum flow rate does not exceed 250 m^3/h or flow rate between 250 and 1000 m^3/h and the manufacturer declares its intended use as being exclusively for a residential ventilation application.*
SEC	–	*Coefficient to express the energy consumed for ventilation per m^2 heated floor area of a dwelling or building.*
Sound power level	–	*Casing-radiated A-weighted sound power level expressed in dB with reference to the sound power of one pW. Transmitted by air at reference airflow.*
SPI	–	*Specific power input means the ratio between the effective power input (in W) and the reference flow rate (in m3/h).*
Thermal efficiency of a residential HRS	–	*Ratio between supply air temperature gain and exhaust air temperature loss both relative to the outdoor temperature, measured under dry condition of HRS, and standard air conditions, with balanced mass flow at reference flow rate at indoor-outdoor temperature difference of 13K, no correction for thermal heat gain from fan motor.*
UVU	–	*Ventilation unit producing an air flow in one direction only, where the mechanically produced air flow is balanced by natural air supply or exhaust.*
VU	–	*Electricity driven appliance equipped with at least one impeller, one motor and a casing and intended to replace utilised air by outdoor air in a building or a part of a building.*
VSD	–	*Electric controller, integrated or functioning as one system or as a separate delivery with the motor and the fan, which continuously adapts the electrical power supplied to the motor in order to control the flow rate.*

1. Introduction

1.1 Ventilation

Ventilation is the intentional introduction of ambient air into a space and is mainly used to control indoor air quality by diluting and displacing indoor pollutants; it can also be used for purposes of thermal comfort or dehumidification. The correct introduction of ambient air will help to achieve desired indoor comfort levels although the measure of which varies from individual to individual [1].

It is being estimated that 60% of energy used for residential buildings and space heating comes from 25% of EU's final energy consumption [2]. There is a great demand in reducing the energy consumption for space heating and cooling in residential buildings [3].

Traditional heating process including wood burning, coal heating cause health illness for people. Incomplete combustion may lead to the emission of volatile gases such as carbon monoxide, nitrogen oxide and other volatile organic compounds, this may result in insufficient oxygen supply inside the house. These incomplete combustions will not provide the correct introduction of the ambient air into the residential space [4].

As the technology grows the traditional heating process are been replaced by modern ventilation units. These ventilation units provide the ambient air supply to the residential buildings providing them to bee ecologically green. Most of the green buildings have ventilation system to provide an ambient atmosphere inside.

Residential ventilation has some basic elements such as ventilation flow rate, airflow direction and airflow pattern or air distribution. These are been the main basic elements that are been followed in every residential ventilation units.

The ventilation flow rate can be referred to as either an absolute ventilation flow rate in l/s or m^3/s, or an air-change rate relative to the volume of the space. In this guideline, the ventilation rate is referred to as the absolute amount of inflow air per unit time (litre per second or l/s, cubic meter per hour or m^3/hr) and the air-change rate as the relative amount of inflow air per unit time

The airflow direction in the residential refers to the overall direction of the flow in the building. This airflow should be from clean zone to dirty zone to provide a ambient atmosphere inside the building

The airflow pattern or air distribution refers that the external air should be delivered to each part of the space in an efficient manner and the airborne pollutants generated in each part of the space should also be removed in an efficient manner.

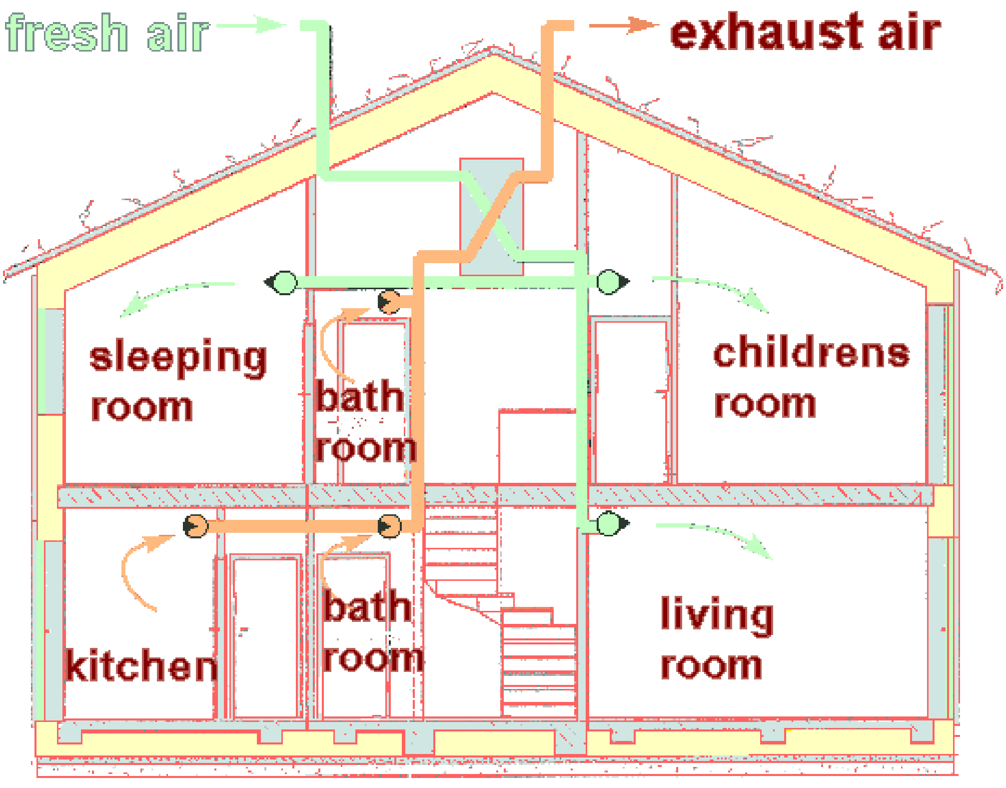


Figure 1 Pictorial representation of basic ventilation in residential building [5]

1.2 Methods of ventilation

Residential ventilation can be achieved by three common methods: natural ventilation, mechanical ventilation and hybrid ventilation

- Natural forces (e.g. winds and thermal buoyancy force due to indoor and outdoor air density differences) drive outdoor air through purpose-built, building envelope openings. Purpose-built openings include windows, doors, solar chimneys, wind towers and trickle ventilators. This natural ventilation of buildings depends on climate, building design and human behaviour.
- Mechanical fans drive mechanical ventilation. Fans can either be installed directly in windows or walls, or installed in air ducts for supplying air into, or exhausting air from, a room. The type of mechanical ventilation used depends on climate. For example, in warm and humid climates, infiltration may need to be minimized or prevented to reduce interstitial condensation (which occurs when warm, moist air from inside a building penetrates a wall, roof or floor and meets a cold surface). In these cases, a positive pressure mechanical ventilation system is often used. Conversely, in cold climates, exfiltration needs to be prevented to reduce interstitial condensation, and negative pressure ventilation is used. For a room with locally generated pollutants, such as a bathroom, toilet or kitchen, the negative pressure system is often used.
- Hybrid (mixed-mode) ventilation relies on natural driving forces to provide the desired (design) flow rate. It uses mechanical ventilation when the natural ventilation flow rate is too low. When natural ventilation alone is not suitable, exhaust fans (with adequate pre-testing and planning) can be installed to increase ventilation rates in rooms housing patients with airborne infection. However, this simple type of hybrid (mixed-mode) ventilation needs to be used with care. The fans should be installed where room air can be exhausted directly to the outdoor environment through either a wall or the roof. The size and number of exhaust fans depends on the targeted ventilation rate, and must be measured and tested before use [6].

1.3 Is natural ventilation enough?

Homes that are been built in olden days do not provide the requires ventilation rate as mentioned in ASHRAE standards. These residential buildings use the natural ventilation which are lower than 15 cmf per person. These values are not accepted by ASHRAE and it suggests using an external ventilation for those residential buildings.

1.4 ASHRAE

ASHRAE stands for the **American Society of Heating, Refrigerating and Air-Conditioning Engineers**. It focuses on building systems, energy efficiency, indoor air quality, refrigeration and sustainability technologies. The ASHRAE Handbook is a four-volume resource for HVAC&R technology and is available in both print and electronic versions. The volumes are Fundamentals, HVAC Applications, HVAC Systems and Equipment, and Refrigeration. One of the four volumes is updated each year. ASHRAE also publishes a set of standards and guidelines relating to HVAC systems and issues, that are often referenced in building codes and used by consulting engineers, mechanical contractors, architects, and government agencies. These standards are periodically reviewed, revised and republished.

1.5 ASHRAE standards

The ASHRAE had a residential ventilation standard since 2003, when ASHRAE 62.2 ("Ventilation and Acceptance Indoor Air Quality in Low-rise Residential Buildings") was first approved for publication. ASHRAE established the basic ventilation formula in 2003 which was unchanged till recently i.e. 7.5 cmf per person + 1 cmf per 100 square feet. When newer version of 62.2 released in 2013, it had a significant change in the ventilation formula. As per the new formula, high performance homes need to be ventilated at a higher rate, i.e. 7.5 cmf per person + 3 cmf per 100 square feet [7].

1.6 Options used for residential ventilation

Apart from natural ventilation there are many other options that are been used for ventilation in residential buildings

- Positive Input Ventilation:

  Positive ventilation uses a mechanical fan to inject fresh air into the house and forces stale air out of the building via natural leakage. The system works continuously and background vents are not normally required, so there is often no need for trickle vents - though sometimes it is necessary to have transfer grilles between rooms to enable ventilation of rooms that do not open directly onto the hall-way. As fresh air is being drawn in mechanically, it can be filtered to remove pollen and other irritants. When installed in a cold roof space (an un-insulated loft) positive ventilation can draw its incoming air from the loft space that is naturally warmer than outside air and therefore requires less heating, helping to improve energy efficiency. Systems are also available with two intakes, one from the loft and another directly from outside at soffit level (the underside of the roof overhang) with a thermostatic control unit that mixes the intakes to your chosen setting, according to whether heating or cooling is required. A third option is to have an intake below the roof tiles which can work as a solar air preheater on sunny days and help to cool incoming air at night.

- Continuous Mechanical Extract Ventilation:

  This is essentially the same as having bathroom extract fans, only instead of individual fans in each wet area, a single central fan is located remotely and ducting is installed to each wet area. This form of ventilation is designed to work at a low background level with an occasional boost when required. It normally removes the need for background ventilation by drawing in air through natural leakage points throughout the house, so there is usually no need for trickle vents or airbricks. Continuous ventilation can also help to keep the house cooler on hot days. Replacement air is at outside temperature and is not filtered. A benefit of such systems is that fan noise can be removed from bathrooms to wherever the unit is located. A central extract fan system can be a more cost-effective alternative to extract fans and background vents in a larger house that has several bathrooms.

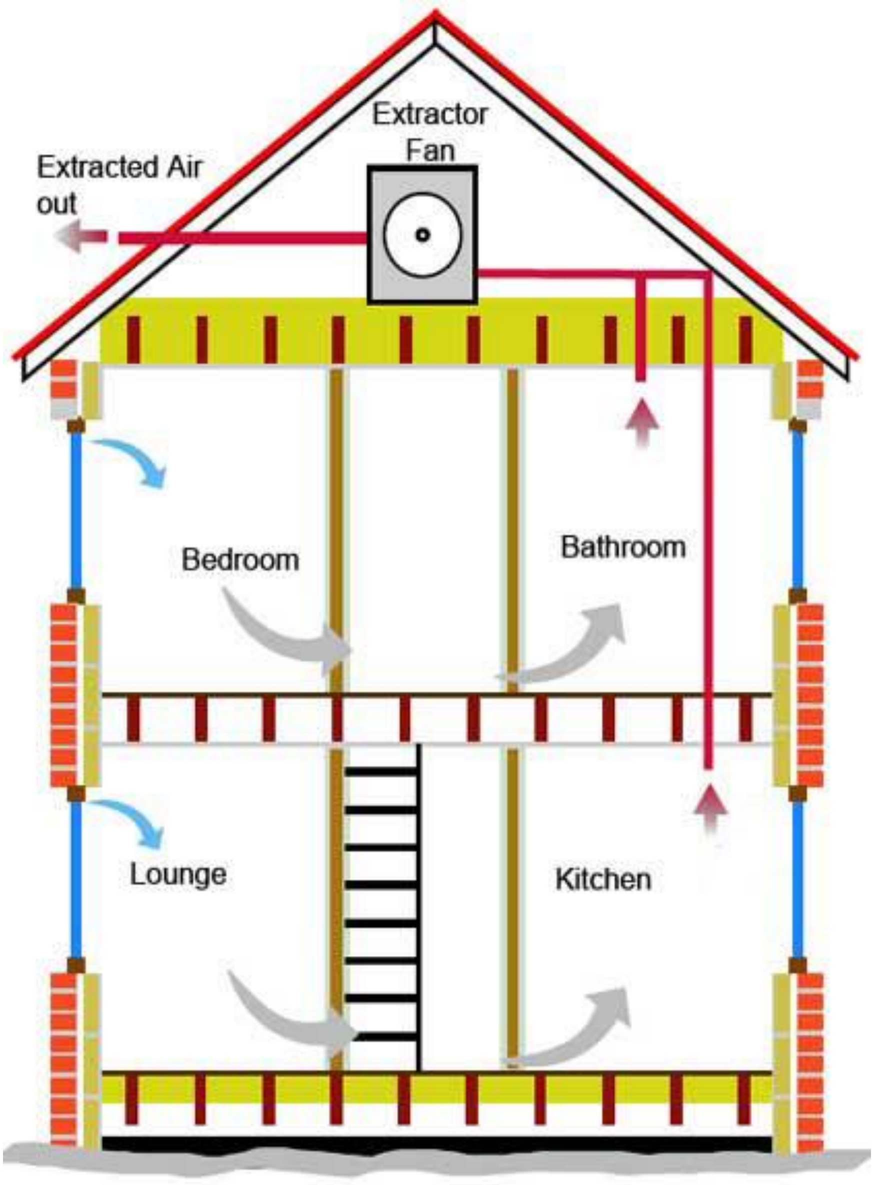


Figure 2 Pictorial representation of continuous mechanical extract ventilation [8]

- Passive stack ventilation system:

Passive vents operate on the principle of convection — the movement of air via currents created by temperature differences inside and outside the house. Passive vents are located in the same places as extract fans, such as kitchens and bathrooms, but as they have no mechanical fans they are silent and use no direct energy. The vents are simply plastic ducts that run from the ceilings of wet areas, up and out through the roof. Some vents have humidistats that adjust the vent opening and therefore the rate of ventilation, in relation to the humidity level. Passive stack ventilation must be used in conjunction with background ventilation, typically trickle vents in windows. The air that enters the building is unfiltered and at outside air temperature. The idea is that the system is controllable and that the inevitable energy loss through ventilation is mitigated by the energy saved by not using electrically powered mechanical fans.

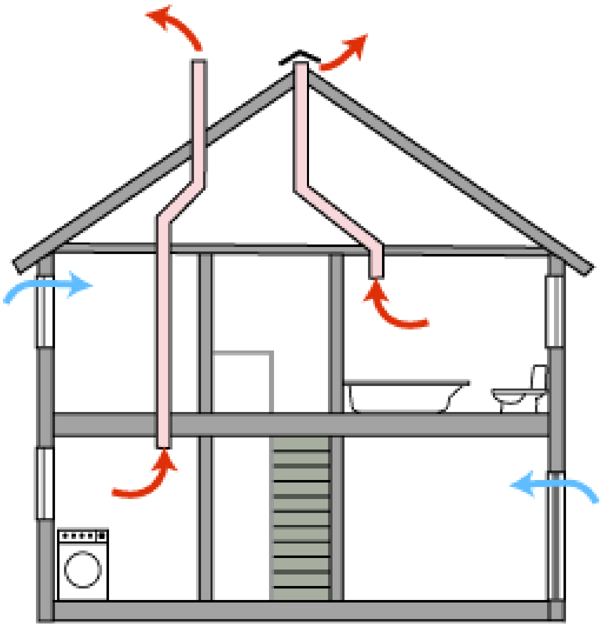


Figure 3 Pictorial representation of passive stack ventilation system [9]

- Central extract ventilation:

Central ventilation system is a ventilation methodology ideal for new build apartments and houses. Consisting a centrally mounted extraction unit, usually located in a loft space or cupboard, it is then ducted around the house to each wet room (bathroom, kitchen) where a ceiling valve acts as the point of extraction.

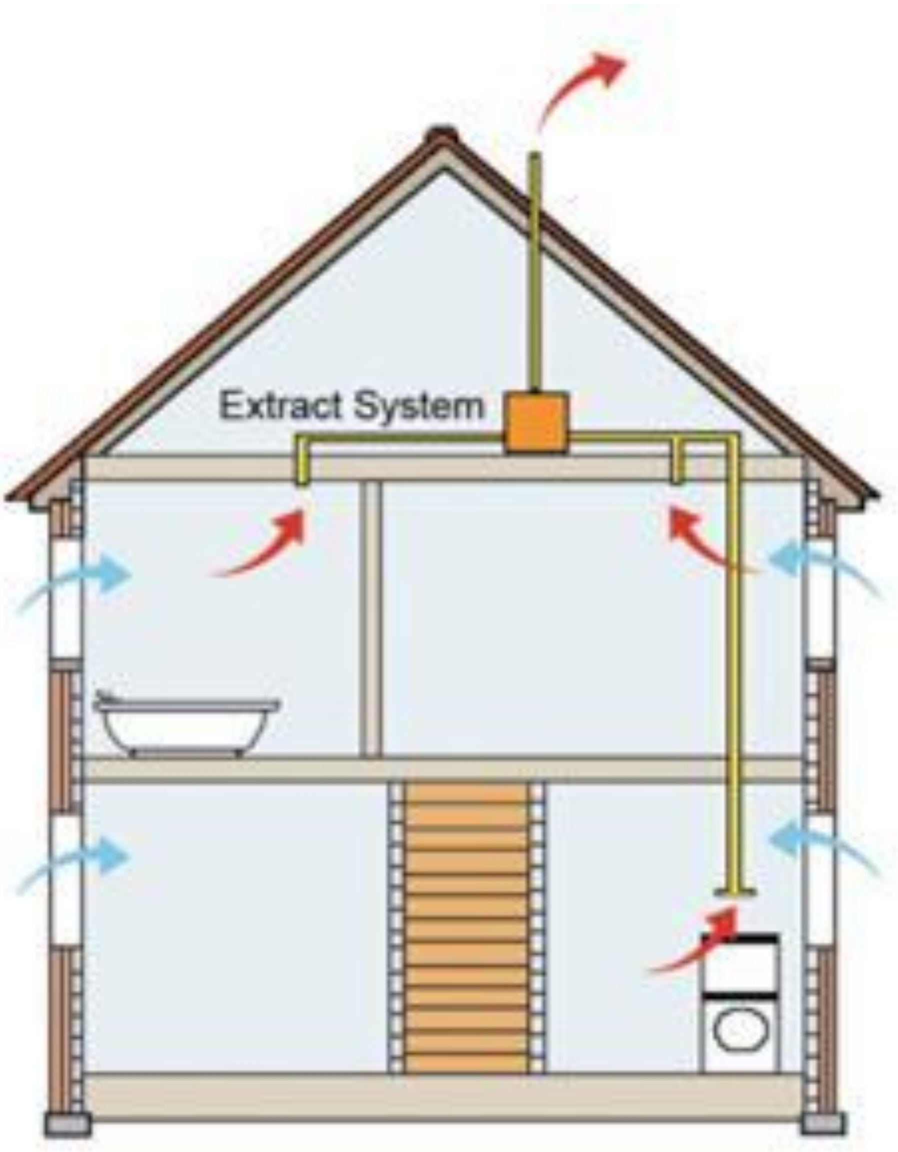


Figure 4 Pictorial representation of central ventilation system [10]

- Heat recovery ventilation:

HRV systems are designed to continuously extract polluted air from moisture- and odor-producing areas such as kitchens and bathrooms. This is done at a low background level with an occasional boost when required. The air is carried via a network of ducts concealed within the building structure, connected to a central mechanical fan unit, usually located in the loft or other out-of-the-way location. Before filtered air from the outside is supplied to 'dry' habitable rooms (bedrooms, living rooms etc.) heat is transferred from the stale air via a heat exchanger in the power unit, with a 70-93% efficiency [11].

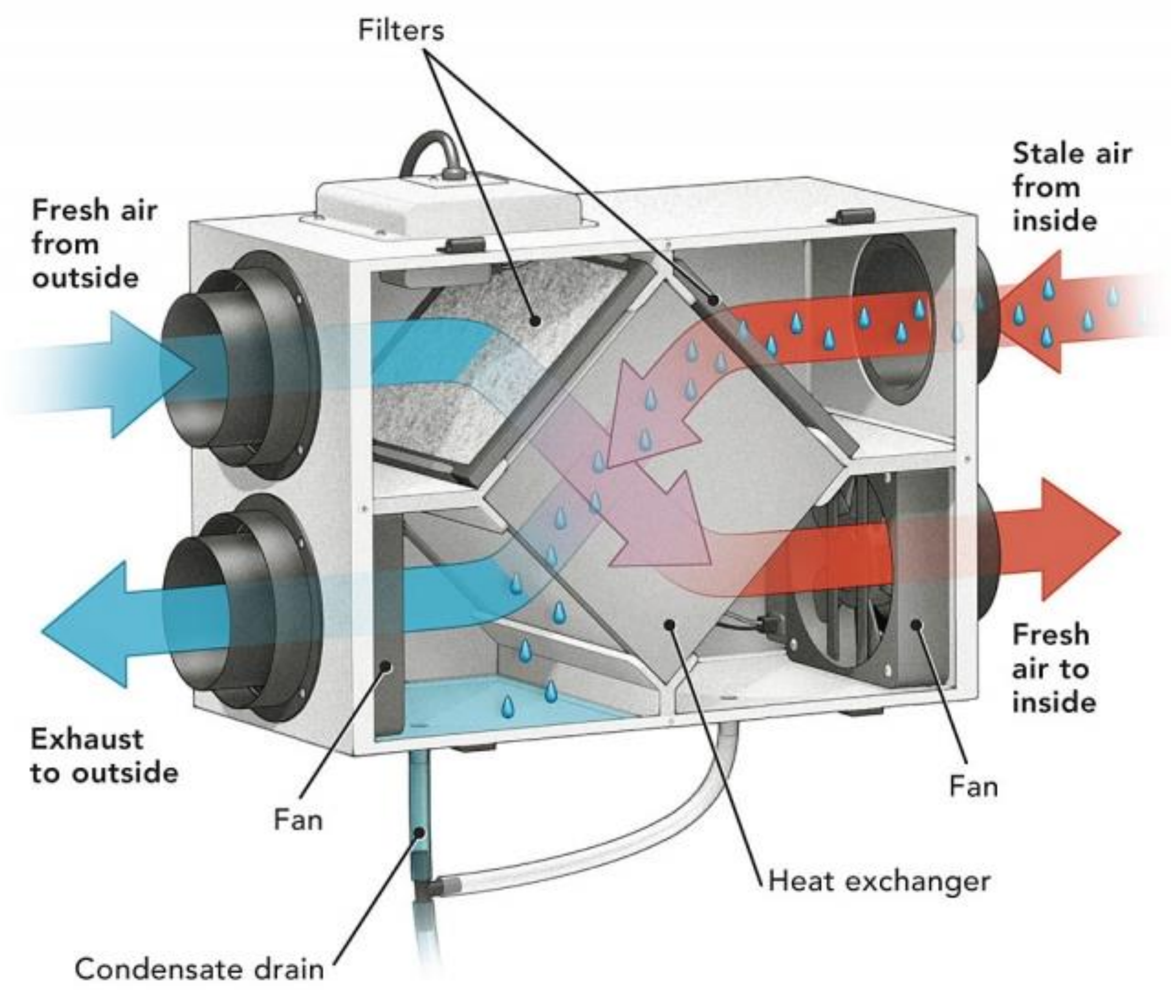


Figure 5 Pictorial representation of HRV [12]

Among the above-mentioned options, the cost effective and efficient method for ventilation in residential building is the Heat recovery ventilation. This type of ventilation use might move as much as 200 cfm of air which is more than enough of the quantity that a ASHRAE is set [13].

1.7 Basic working and types of HRV

A heat recovery system can work via a ventilation system which is positioned at the top of the building. Rather than just draw the stale air out and replace it with new stuff, it first of all works to draw the heat from the outgoing air and passes it to the air which is coming in. Heat recovery ventilation works independently of your normal heating system. In each room there are ventilation ducts with filters that feed the air in and out of the space, all leading to a heat exchanger that is either placed in the loft or on the roof of a building. This heat exchanger is the brain of the heat recovery system, moving the stale air through hundreds of small pipes whilst drawing in cold air from outside in other ducts. These flow past each other without mixing physically but the heat is drawn from the stale air to the cold air, which is then fed back down into the pipes and into the rooms. The stale air, minus its heat, is then expelled into the atmosphere. The technology for heat recovery systems has improved dramatically over the years and there are now systems available that profess to extract up to 90% of the heat from stale air and return it to the fresh air that is circulating back into the system. The world of heat recovery is, of course, far more complex than this, and has applications in all aspects of our lives, not just through the ventilation system, though the principals of heat collection are largely the same [14].

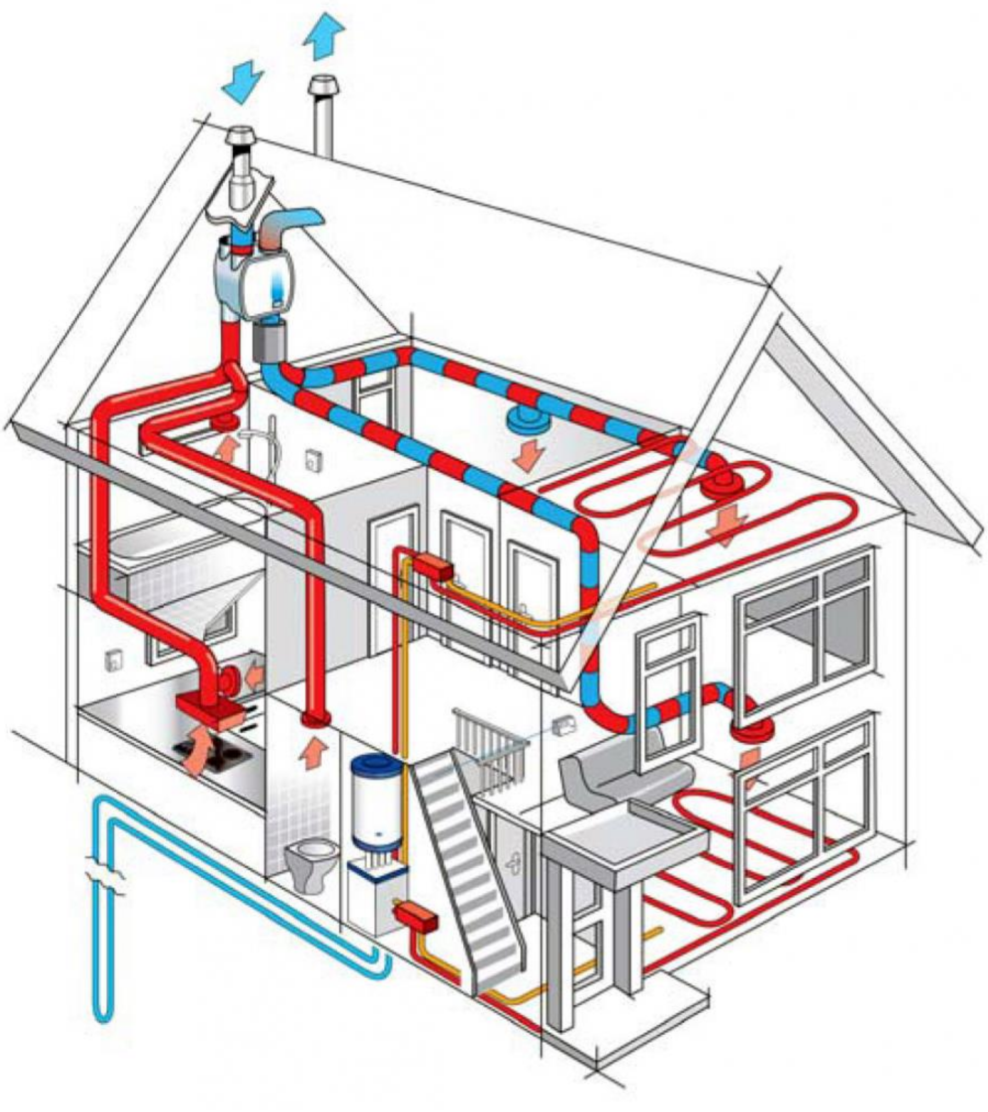


Figure 6 Pictorial representation of whole house heat recovery ventilation [15]

Mainly there are two types of heat recovery systems which we are using for our calculation purpose are listed below

- Recuperative heat exchanger – Heat transfers continuously from hot fluid to the cold fluid through a dividing wall. There is no direct mixing of the fluids. Some examples are tubular, plate type and extended surface exchanger.

- Regenerative heat exchanger – Operation involves the temporary storage of heat from hot fluid which is transferred in a packing which possess the necessary thermal capacity to the cold fluid. This is accomplished by bringing hot fluid in contact with the heat storage medium and then introducing cold fluid which absorbs the heat. Some examples are rotary, fixed bed heat exchanger.

1.8 Schedule

The pursuit of the objectives which are set to achieve for the completion of this thesis are calendarized and same is shown in the below figure.

Task Name	Duration	Start	Finish	Predecess
Document study	2 wks	Tue 28-03-17	Mon 10-04-17	
Data collecting for calculation	3 wks	Tue 11-04-17	Mon 01-05-17	1
Preparing microsoft xl sheet for calculation purpose	2 wks	Tue 02-05-17	Mon 15-05-17	2
Calculations are made and compared with document	2 wks	Tue 16-05-17	Mon 29-05-17	3
Discussing and finalising calculation document	1 wk	Tue 30-05-17	Mon 05-06-17	4
Thesis writing - Thesis development part	4 wks	Tue 06-06-17	Mon 04-09-17	5
Gathering more information for introduction and bibilographic work	1 wk	Tue 05-09-17	Mon 11-09-17	6
Thesis writing - Conclusion and Future work	1 wk	Tue 12-09-17	Mon 18-09-17	7
Thesis writing - Introduction and Bibilography	1 wk	Tue 19-09-17	Mon 25-09-17	8
Thesis writing - Annex	0.5 wks	Tue 26-09-17	Thu 28-09-17	9
Thesis writing as per template	4 wks	Thu 28-09-17	Thu 26-10-17	10
Changes are made as per guides instructions and finalizing thesis document	1.5 wks	Thu 26-10-17	Mon 06-11-17	11

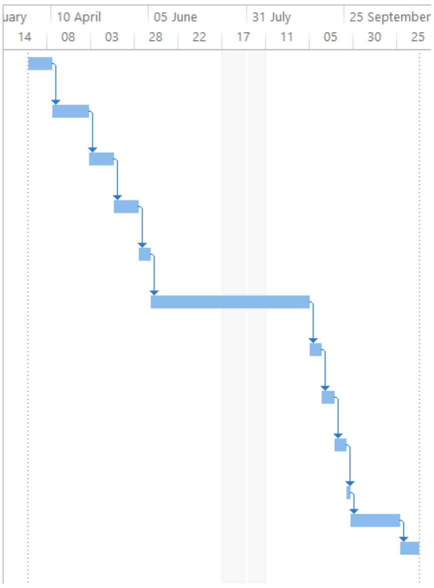


Figure 7 Project schedule

1.9 Organization of the report

In chapter 1 Introduction, which gives the basic idea of the ventilation unit and about the various type of ventilation, ASHRAE standards. In chapter 2 Bibliography work, the

Regulation’s [16] subject and scope are being elaborated and discussed. In chapter 3 Thesis development, the calculation method that is stated by the Regulation [16] is been applied to the selected manufacturers from different regions and is verified. In the chapter 4 Conclusion, the obtained results are being analyzed and compared to obtain a best conclusion. In the final chapter 5 Annexes, the supporting documents of calculation, formulation and classification are been elaborated.

2. Bibilographic Work

2.1 European commission for energy labelling for residential ventilation units

2.1.1 Objective

"COMMISSION DELEGATED REGULATION (EU) No 1254/2014 of 11 July 2014" supplementing Directive 2010/30/EU of the European Parliament and of the Council with regards to energy labelling of Residential Ventilation Units states the following points [16]

1. The delegated acts are to be adopted where products represent a significant potential for energy savings and present a wide disparity in performance levels although having an equivalent functionality and no other Union legislation or self-regulation is expected to achieve the policy objectives more quickly or at lesser expense than mandatory requirements.
2. This commission has also assessed the technical, environmental and economic aspects of the RVU and it also assessed the energy consumption of the RVU which intend to be a significant part of the total household energy demand in the union.

Improvements have been done to achieve the energy efficiency but there is significant scope to further reduce the energy consumption of such units.

3. Commission has been elaborated that this energy labelling system is not meant for ventilation units with power input less than 30 W per air stream, non-residential ventilation units, units designed for use in hazardous region, malfunction units which predominantly heat or cool.
4. The sound power level of the residential ventilation units which is the sound produced in the casing of the unit should be mentioned in the label which is important for the consumer.
5. The combined effect of this Regulation and Commission is expected to increase the aggregated saving from 1300 PJ to 4130 PJ (which is 45%) by 2025
6. The information that is been printed on the label should be obtained by reliable, accurate and reproducible methods. These should take into account the reliable measurement and calculation methods that are been mentioned in the Regulation [17].
7. the Regulation should specify all the information in order to uniform the design and content of the label, technical documents and the fiche for all the manufacturers. This information should be compulsorily produced in any kind of distance selling or advertisements in any form either in hard bound paper or via internet.

2.1.2 Scope

1. This regulation establishes the energy labelling only for the Residential Ventilation Units (RVU)
2. The Residential Ventilation Units which are excluded from this Regulation:
    a. are unidirectional (exhaust or supply) with an electric power input less than 30 W.
    b. are exclusively manufactured to perform in potentially explosive atmosphere as explained in Directive 94/9/EC of the European Parliament and of the Council [18].
    c. are exclusively made for emergency use, for a short period of time and which are made taken into consideration of the construction work for safety in case of fire as set out in Regulation (EU) No 305/2011 of the European Parliament and of the Council [19].
    d. are exclusively specified as operating:

i. Where the operating temperature of the air exceeds 100 ^{o}C.
ii. Where in case the operating temperature of the motor if located the air stream, driving fan exceeds 65 ^{o}C.
iii. Where the temperature of the air being moved or the ambient operating temperature of the motor, if located outside the air stream goes below -40 ^{o}C.
iv. where the supply voltage exceeds 1000 V AC or 1500 V DC
v. in environments which are toxic, highly corrosive or flammable or in environments with abrasive substances.

e. include a heat exchanger and a heat pump for heat recovery, or allowing heat transfer or extraction being additional to that of the heat recovery system, except heat transfer for frost protection or defrosting.
f. are classified as range hoods covered by Commission Delegated Regulation (EU) No 65/2014 [20].

3. Thesis Development

3.1 Methodology

3.1.1 Basic procedure used by Regulation

As per the COMMISSION DELEGATED REGULATION (EU) No 1254/2014 of 11 July 2014, the calculation of the SEC, SPI, AHS, AEC values are driven from the formulas given in the Regulation. These formulas are been mentioned in the fore coming sections

These formulas basically consist of 4 group of parameters, which are

a. Default values which doesn't affected by climatic change or type of machine used, which are specific heat capacity(C_{air}), net ventilation(q_{net}), natural ventilation rate(q_{ref}), annual operating hours(t_a), primary energy factor electric power generation and distribution(pef) and space heating efficiency(η_h).
b. Values which are mentioned by the manufactures for that particular product, which are specific power input(SPI) and thermal efficiency of the heat exchanger(η_t).
c. Values which are selected based on the data provided by the manufacturer for that product, which are general typology ventilation system, type of control system used by that ventilation unit, type and drive characteristics of the motor used by that product, type of heat exchanger used by that product.

d. Values which bound to external climatic condition when they are working i.e. during cold, average or warm temperature.

Additional data which are provided for that machine-like sound power level(L_{WA}) and maximum airflow rate are used in the labelling of that product along with the product classification.

3.1.2 Formulas

1. Specific energy consumption SEC [$kWhm^{-2}a^{-1}$]:

$$SEC = [t_a \times pef \times q_{net} \times MISC \times CTRL^x \times SPI] - [t_h \times \Delta T_h \times \eta^{-1}_h \times c_{air} \times \{q_{ref} - (q_{net} \times CTRL \times MISC \times (1 - \eta_t)\}] + Q_{defr}. \qquad \textbf{(1)}$$

Where,

- SEC is the specific energy consumption for ventilation per m2 heated floor area of a dwelling or building [$kWh/m^2.a$].
- t_a is annual operating hours [h/a].
- pef is the primary energy factor for electric power generation and distribution [-].
- q_{net} is net ventilation rate demand per m^2 heated floor area [$m^3/h.m^2$].
- MISC is an aggregated general typology factor, incorporating factors for ventilation effectiveness, duct leakage and extra infiltration [-].
- CTRL is the ventilation control factor [-].
    - x is an exponent that takes into account non-linearity between thermal energy and electricity saving, depending on motor and drive characteristics [-].
- SPI is specific power input [$kW/(m^3/h)$].
    - SPI = rated power/air volume
- t_h is total hours heating season [h].
- ΔT_h is the average difference in indoor (19 °C) and outdoor temperature over a heating season, minus 3 K correction for solar and internal gains [K].
- η_h is the average space heating efficiency [-].
- C_{air} is the specific heat capacity of air at constant pressure and density [$kWh/(m^2K)$].
- q_{ref} is the reference natural ventilation rate per m2 heated floor area [$m^3/h.m^2$].
- η_t is the thermal efficiency of heat recovery [-].

- Q_{dref} is the annual heating energy per m2 heated floor area [kWh/(m^2.a)] for defrosting, based on a variable electric resistance heating.

2. Annual heating energy:

$$Q_{defr} = t_{defr} \times \Delta T_{defr} \times c_{air} \times q_{net} \times pef. \quad \textbf{(2)}$$

Q_{defr} applies only to bidirectional units with recuperative heat exchanger and for unidirectional units or units with regenerative heat exchangers, $Q_{defr} = 0$.

Where,

- t_{derf} is the duration of the defrosting period, i.e. when the outdoor temperature is below – 4 °C [h/a].
- ΔT_{derf} is the average difference in K between the outdoor temperature and – 4 °C during the defrosting period.

Q_{defr} applies only to bidirectional units with recuperative heat exchanger; for unidirectional units or units with regenerative heat exchangers, $Q_{defr} = 0$.

3. The annual electricity consumption per 100 m2 floor area (AEC) (in kWh/a electric per year); and the annual heating saved ((AHS), which means the annual saving in consumption of energy for heating (in kWh fuel gross calorific value per year) are calculated as follows, using the definitions mentioned above, and the default values in the fore coming part, for each type of climate (average, warm and cold).

Annual electricity consumption (kWha^{-1} electricity):

$$AEC= (t_a \times q_{net} \times MISC \times CTRL^x \times SPI) + Q_{defr}. \quad \textbf{(3)}$$

Annual heating saved (kWha^{-1} gross calorific value):

$$AHS = t_h \times \Delta T_h \times \eta^{-1}{}_h \times c_{air} \times (q_{ref} - (q_{net} \times CTRL \times MISC \times (1 - \eta_t)). \quad \textbf{(4)}$$

Energy Usage (kWh):

$$\text{Energy usage} = \textit{Input energy} \times \textit{total working hours} \quad \textbf{(5)}$$

3.1.3 Calculation parameters and constant values as per Regulation

1. MISC

Table 1 MISC value for RVUs [16]

General typology	MISC
Ducted ventilation unit	1.1
Non-ducted ventilation unit	1.21

2. CTRL

Table 2 CTRL values based on Ventilation control [16]

Ventilation control	CTRL
Manual control (no DCV)	1
Clock control (no DCV)	0.95
Central demand control	0.85
Local demand control	0.65

3. *x* – Value

Table 3 *x* – value based on motor and drive of RVUs [16]

Motor and Drive	*x* - value
On/Off and single speed	1
2 – speed	1.2
3 – speed	1.5
Variable speed	2

4. Constants based on climate

Table 4 Constant values based on climate used for calculation [16]

Climate	T_h in h	ΔT_h in k	T_{defr} in h	ΔT_{defr} in k	Q_{defr} (*) in $kWh/a.m^2$
Cold	6552	14.5	1003	5.2	5.85
Average	5112	9.5	168	2.4	0.45
Warm	4392	5	-	-	-

* Defrosting applies only to bidirectional units with recuperative heat exchanger and is calculated as

$$Q_{defr}=t_{defr}*\Delta T_{defr}*C_{air}*q_{net}*pef$$

* For unidirectional units or units with regenerative heat exchangers,

$$Q_{derf} = 0$$

5. Other constant values

Table 5 Constant values used for calculation [16]

Defaults	Values
C_{air}	0.0003444
q_{net}	1.3
q_{ref}	2.2
t_a	8760
pef	2.5
η_h	75%

3.2 Calculation

1) Manufacturer 1

a) Specifications [21]

General typology: Ducted ventilation unit

Ventilation control: Local demand

Motor and drive characteristics: Variable speed

Maximum airflow: 850 m^3/h

SPI: 0.24 $W/(m^3/h)$

Heat exchanger type: Rotary (belongs to Regenerative heat exchanger)

Thermal efficiency of heat exchanger: 87%

Sound power level: 43 dB(A)

Input energy: 0.49 kW

b) Calculating parameters

MISC = 1.1

CTRL = 0.65

x-value = 2

Q_{defr} = 0

c) SEC calculation

Table 6 SEC calculation for manufacturer 1

Climate	MISC	η_t	SPI [$kW/(m^3/h)$]	t_h [h]	ΔT_h [K]	CTRL	$CTRL^x$	SEC [kWh/m3.a]
Cold	1.1	0.87	0.00024	6552	14.5	0.65	0.4225	-87.4
Average	1.1	0.87	0.00024	5112	9.5	0.65	0.4225	-43.1
Warm	1.1	0.87	0.00024	4392	5	0.65	0.4225	-17.8

d) AEC & AHS calculation

Table 7 AEC and AHS calculation for manufacturer 1

Climate	MISC	C_{air} [kWh/m³.K]	t_h	Q_{defr} [kWh/a.m²]	η^{-1}_h	AEC [kWh/a]	AHS [kWh/a]
Cold	1.1	0.000344	6552	0	1.3333	127	9059.9
Average	1.1	0.000344	5112	0	1.3333	127	4631.3
Warm	1.1	0.000344	4392	0	1.3333	127	2094.2

e) SEC classification

The annex 1 explains about the labelling and classification system based on the obtained SEC value. Annex 1 states that the product should be classified based on the SEC value of average climatic condition and this product is classified as **A+**.

2) Manufacturer 2

a) Specifications [22]

General typology: Ducted ventilation unit

Ventilation control: Local demand

Motor and drive characteristics: Variable speed

Maximum airflow: 350 m^3/h

SPI: 0.571 W/(m^3/h)

Heat exchanger type: Aluminium (belongs to Recuperative heat exchanger)

Thermal efficiency of heat exchanger: 90%

Sound power level: 30 dB(A)

Input energy: 0.56 kW

b) Selecting calculating parameters

MISC = 1.1

CTRL = 0.65

x-value = 2

c) SEC calculation

Table 8 SEC calculation for manufacturer 2

Climate	MISC	η_t	SPI [kW/(m³/h)]	t_h [h]	ΔT_h [K]	CTRL	$CTRL^x$	SEC [kWh/m3.a]
Cold	1.1	0.90	0.000571	6552	14.5	0.65	0.4225	-78.4
Average	1.1	0.90	0.000571	5112	9.5	0.65	0.4225	-38.9
Warm	1.1	0.90	0.000571	4392	5	0.65	0.4225	-13.7

d) AEC & AHS calculation

Table 9 AEC and AHS calculation for manufacturer 2

Climate	MISC	C_{air} [kWh/m³.K]	t_h	Q_{defr} [kWh/a.m²]	$\eta^{-1}{}_h$	AEC [kWh/a]	AHS [kWh/a]
Cold	1.1	0.000344	6552	5.82	1.3333	884.4	9181.5
Average	1.1	0.000344	5112	0.45	1.3333	347.4	4693.4
Warm	1.1	0.000344	4392	0	1.3333	302.4	2122.3

e) SEC classification

The annex 1 explains about the labelling and classification system based on the obtained SEC value. Annex 1 states that the product should be classified based on the SEC value of average climatic condition and this product is classified as **A**.

3) Manufacturer 3

a) Specifications [23]

General typology: Ducted ventilation unit

Ventilation control: Manual control

Motor and drive characteristics: Variable speed

Maximum airflow: 889 m^3/h

SPI: 0.26 $W/(m^3/h)$

Heat exchanger type: Rotary (belongs to Regenerative heat exchanger)

Thermal efficiency of heat exchanger: 79.4%

Sound power level: 47 dB(A)

Input energy: 0.84 kW

b) Selecting calculating parameters

MISC = 1.1

CTRL = 1

x-value = 2

Q_{defr} = 0

c) SEC calculation

Table 10 SEC calculation for manufacturer 3

Climate	MISC	η_t	SPI [kW/(m³/h)]	t_h [h]	ΔT_h [K]	CTRL	$CTRL^x$	SEC [kWh/m3.a]
Cold	1.1	0.794	0.00026	6552	14.5	1	1	-74.9
Average	1.1	0.794	0.00026	5112	9.5	1	1	-34.3
Warm	1.1	0.794	0.00026	4392	5	1	1	-11.05

d) AEC & AHS calculation

Table 11 AEC and AHS calculation for manufacturer 3

Climate	MISC	C_{air} [kWh/m³.K]	t_h	Q_{defr} [kWh/a.m²]	$\eta^{-1}{}_h$	AEC [kWh/a]	AHS [kWh/a]
Cold	1.1	0.000344	6552	0	1.3333	325.7	8302.9
Average	1.1	0.000344	5112	0	1.3333	325.7	4244.3
Warm	1.1	0.000344	4392	0	1.3333	325.7	1919.2

e) SEC classification

The annex 1 explains about the labelling and classification system based on the obtained SEC value. Annex 1 states that the product should be classified based on the SEC value of average climatic condition and this product is classified as **A**.

4) **Manufacturer 4**

a) **Specifications [24]**

General typology: Ducted ventilation unit

Ventilation control: Manual control

Motor and drive characteristics: Variable speed

Maximum airflow: 288 m^3/h

SPI: 0.58 $W/(m^3/h)$

Heat exchanger type: Rotary (belongs to Regenerative heat exchanger)

Thermal efficiency of heat exchanger: 80%

Sound power level: 29 dB(A)

Input energy: 1.6 kW

b) **Selecting calculating parameters**

MISC = 1.1

CTRL = 1

x-value = 2

Q_{defr} = 0

c) **SEC calculation**

Table 12 SEC calculation for manufacturer 4

Climate	MISC	η_t	SPI [kW/(m³/h)]	t_h [h]	ΔT_h [K]	CTRL	$CTRL^x$	SEC [kWh/m3.a]
Cold	1.1	0.8	0.00058	6552	14.5	1	1	-65.2
Average	1.1	0.8	0.00058	5112	9.5	1	1	-24.5
Warm	1.1	0.8	0.00058	4392	5	1	1	-1.1

d) AEC & AHS calculation

Table 13 AEC and AHS calculation for manufacturer 4

Climate	MISC	C_{air} [kWh/m^3.K]	t_h	Q_{defr} [kWh/a.m^2]	$\eta^{-1}{}_h$	AEC [kWh/a]	AHS [kWh/a]
Cold	1.1	0.000344	6552	0	1.3333	726.6	8340.3
Average	1.1	0.000344	5112	0	1.3333	726.6	4263.3
Warm	1.1	0.000344	4392	0	1.3333	726.6	1927.8

e) SEC classification

The annex 1 explains about the labelling and classification system based on the obtained SEC value. Annex 1 states that the product should be classified based on the SEC value of average climatic condition and this product is classified as **C**.

5) Manufacturer 5

a) Specifications [25]

General typology: Ducted ventilation unit

Ventilation control: Manual control

Motor and drive characteristics: Variable speed

Maximum airflow: 300 m^3/h

SPI: 0.26 W/(m^3/h)

Heat exchanger type: Aluminium (belongs to Recuperative heat exchanger)

Thermal efficiency of heat exchanger: 85%

Sound power level: 55 dB(A)

Input energy: 0.75 kW

b) Selecting calculating parameters

MISC = 1.1

CTRL = 1

x-value = 2

c) **SEC calculation**

Table 14 SEC calculation for manufacturer 5

Climate	MISC	η_t	SPI [kW/(m³/h)]	t_h [h]	ΔT_h [K]	CTRL	$CTRL^x$	SEC [kWh/m3.a]
Cold	1.1	0.85	0.00026	6552	14.5	1	1	-76.2
Average	1.1	0.85	0.00026	5112	9.5	1	1	-38.6
Warm	1.1	0.85	0.00026	4392	5	1	1	-14.4

d) **AEC & AHS calculation**

Table 15 AEC and AHS calculation for manufacturer 5

Climate	MISC	C_{air} [kWh/m³.K]	t_h	Q_{defr} [kWh/a.m²]	$\eta^{-1}{}_h$	AEC [kWh/a]	AHS [kWh/a]
Cold	1.1	0.000344	6552	5.82	1.3333	907.7	8527.2
Average	1.1	0.000344	5112	0.45	1.3333	370.7	4358.9
Warm	1.1	0.000344	4392	0	1.3333	325.7	1971.1

e) **SEC classification**

The annex 1 explains about the labelling and classification system based on the obtained SEC value. Annex 1 states that the product should be classified based on the SEC value of average climatic condition and this product is classified as **A**.

6) Manufacturer 6

a) **Specifications [26]**

General typology: Ducted ventilation unit

Ventilation control: Manual control

Motor and drive characteristics: Variable speed

Maximum airflow: 165 m^3/h

SPI: 0.30 $W/(m^3/h)$

Heat exchanger type: Aluminium (belongs to Recuperative heat exchanger)

Thermal efficiency of heat exchanger: 91%

Sound power level: 49 dB(A)

Input energy: 0.89 kW

b) Selecting calculating parameters

MISC = 1.1

CTRL = 1

x-value = 2

c) SEC calculation

Table 16 SEC calculation for manufacturer 6

Climate	MISC	η_t	SPI [kW/(m³/h)]	t_h [h]	ΔT_h [K]	CTRL	$CTRL^x$	SEC [kWh/m3.a]
Cold	1.1	0.91	0.00030	6552	14.5	1	1	-75.1
Average	1.1	0.91	0.00030	5112	9.5	1	1	-36.3
Warm	1.1	0.91	0.00030	4392	5	1	1	-11.5

d) AEC & AHS calculation

Table 17 AEC and AHS calculation for manufacturer 6

Climate	MISC	C_{air} [kWh/m³.K]	t_h	Q_{defr} [kWh/a.m²]	$\eta^{-1}{}_h$	AEC [kWh/a]	AHS [kWh/a]
Cold	1.1	0.000344	6552	5.82	1.3333	957.8	8901.1
Average	1.1	0.000344	5112	0.45	1.3333	420.8	4550
Warm	1.1	0.000344	4392	0	1.3333	375.8	2057.5

e) SEC classification

The annex 1 explains about the labelling and classification system based on the obtained SEC value. Annex 1 states that the product should be classified based on the SEC value of average climatic condition and this product is classified as **A**.

3.3 Result

3.3.1 comparison between SEC and SPI of different manufacturers for the average temperature condition

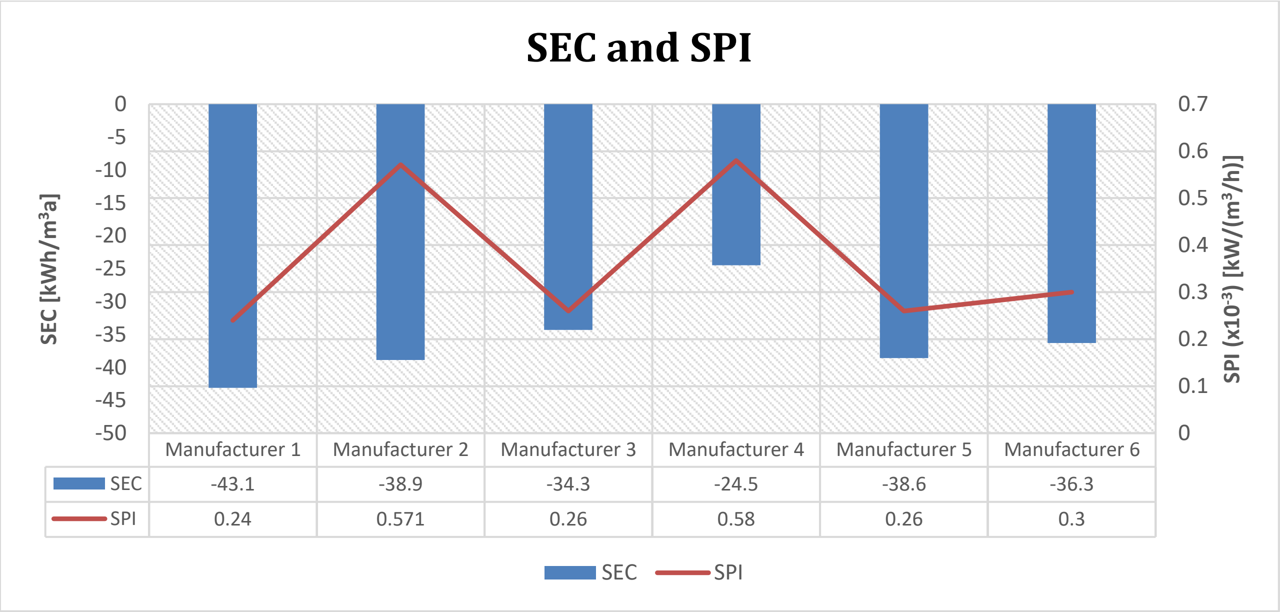


Figure 8 Comparison of SEC and SPI

i. The above stated graph shows the comparison between the SPI and SEC values of the different manufacturers for the average temperature.

ii. It is noted that the SEC values and SPI values of the manufacturers have a inline relation between them about their changes.

iii. This increase is not for all the manufacturers. Considering manufacturer 2 and manufacturer 5, it is noted that both have similar SEC values but have a drastically different SPI values. This is due to the variable input parameters that been used in the calculation of SEC and the type of heat exchanger used.

iv. The main factors that affects the SEC value is the thermal efficiency, SPI value, and the type of ventilation control. Manufacturer 2 has a local demand ventilation and the rated power with respect to maximum flow rate has a slight variation comparing to other manufacturers which leads to a change in SPI value. This change in SPI value affects the SEC value.

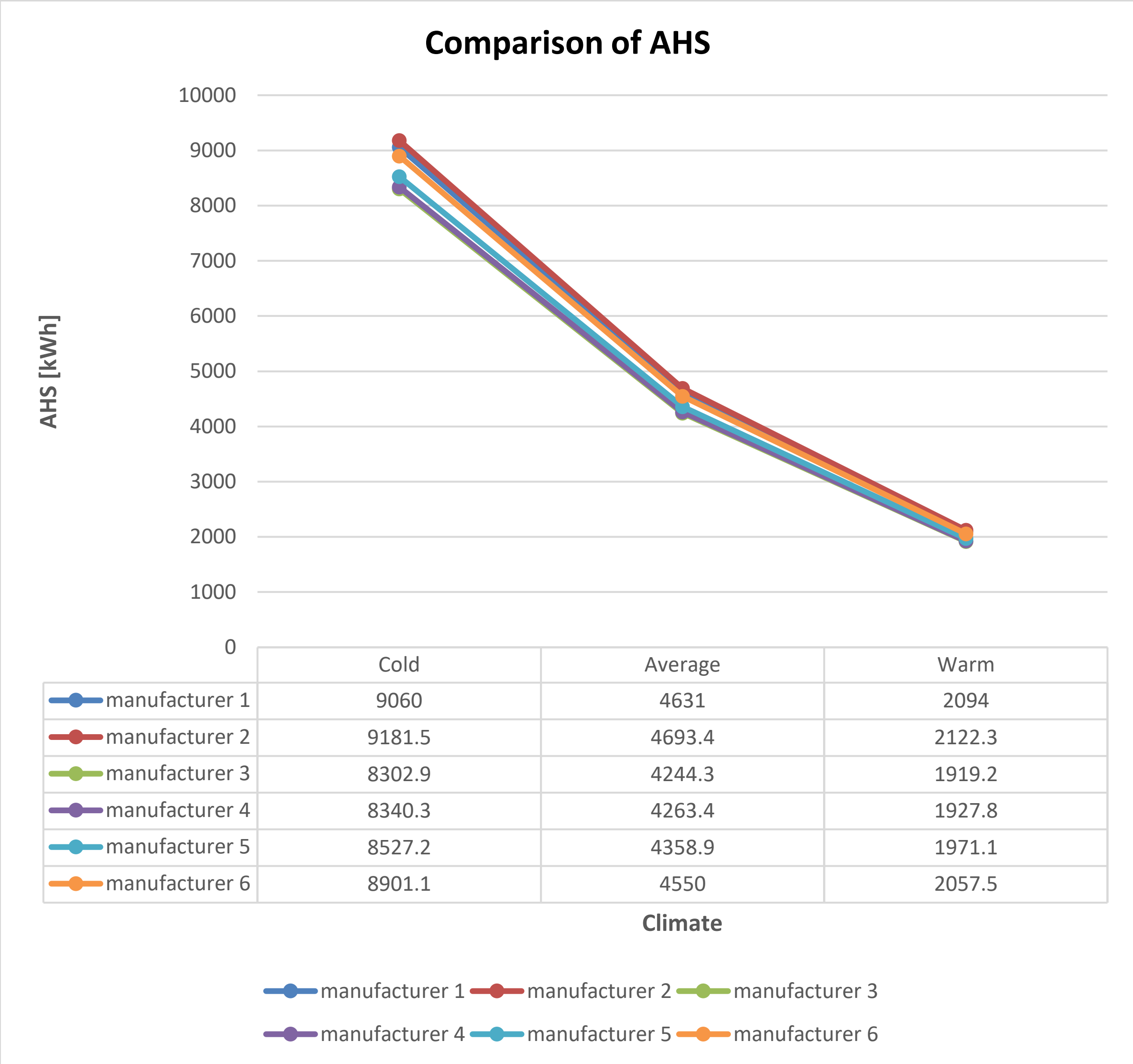
v. Manufacturer 2, manufacturer 5 and manufacturer 6 has recuperative heat exchanger attached to the ventilation units which leads to change in Q_{defr} which changes the value of SEC.

vi. Considering manufacturer 5 and manufacturer 4 it is observed that both have same SPI values but different SEC values. This is due to the ratio of the rated power and maximum flow rate are same in both the manufacturers irrespective of difference in their values.

vii. The change in SEC value for the same SPI value for manufacturer 3 and manufacturer 5 is due to different type of the ventilation unit. Manufacturer 3 has Regenerative heat exchanger whereas manufacturer 5 has Recuperative heat exchanger, that changes the value of Q_{defr} thereby changing SEC value.

viii. From the above graph it is clear that SEC and SPI are directly proportional i.e. as the value of SEC increases the corresponding value of SPI also increases.

3.3.2 Comparison of AHS values of different manufactures for different climate conditions



	Cold	Average	Warm
manufacturer 1	9060	4631	2094
manufacturer 2	9181.5	4693.4	2122.3
manufacturer 3	8302.9	4244.3	1919.2
manufacturer 4	8340.3	4263.4	1927.8
manufacturer 5	8527.2	4358.9	1971.1
manufacturer 6	8901.1	4550	2057.5

Figure 9 Comparison between AHS values of Different manufacturers for different climatic conditions

i. The above stated graph shows the comparison between the AHS values of different manufacturers for three different climatic conditions.

ii. The graph seems to be in the same pattern for all the manufacturers regardless their difference in values.

iii. It may be noted that the value of AHS is low in warm climate compared to other two climatic condition, this is because there will be no defrosting rate in warm temperature there by reducing the value of t_h and ΔT_h and also making t_{defr}, ΔT_{defr}, Q_{defr} equal to zero.

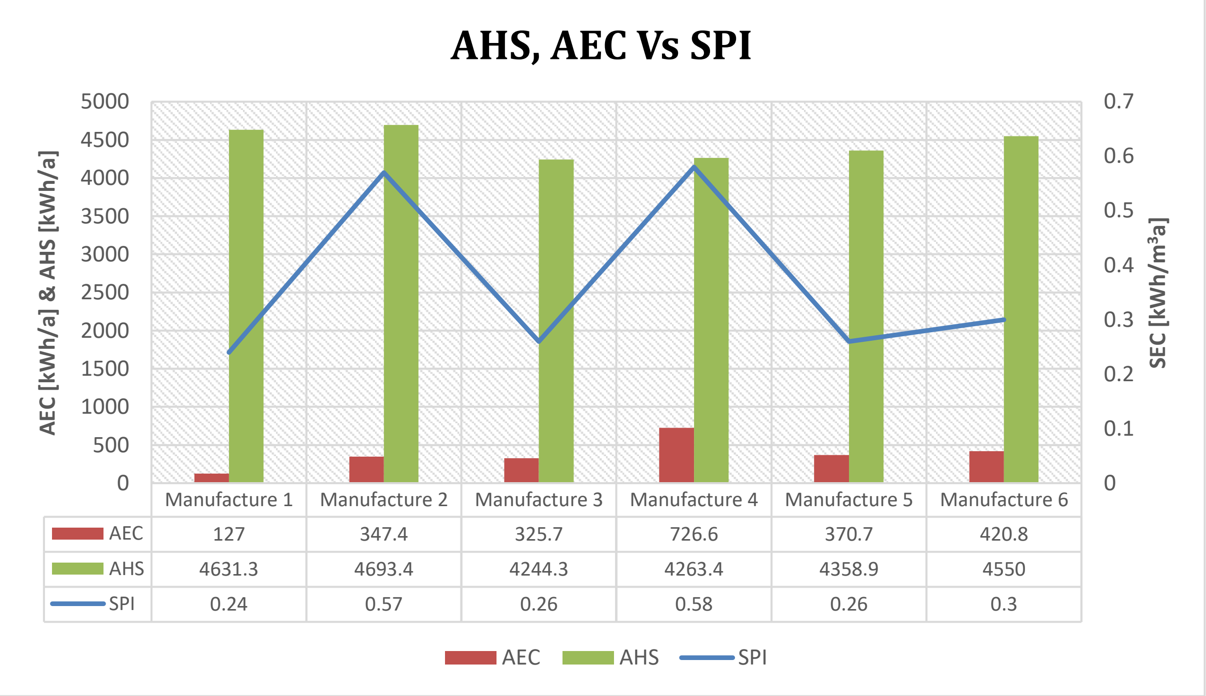
iv. The value of AHS also depends on the type of the ventilation unit and the type of ventilation control thereby the values of MISC and CTRL play a minor role in the change of values

v. The value of AHS also depends on the SEC and SPI value for all the climatic condition. It can be noted that the value of SEC will increase for the increase of AHS.

vi. When there is more need of heat then the energy consumption will increase due to the workload of the RVU, there by this explains the relation between SEC, SPI and AHS.

vii. The above stated graph concludes that the value of AHS depends mainly on the climatic conditions. The cold climate has a higher value of AHS compared to average climatic condition. So the value of AHS reduces from cold, average, warm respectively.

3.3.3 Comparison between AEC, AHS and SPI of different manufactures for average climatic condition



	Manufacture 1	Manufacture 2	Manufacture 3	Manufacture 4	Manufacture 5	Manufacture 6
AEC	127	347.4	325.7	726.6	370.7	420.8
AHS	4631.3	4693.4	4244.3	4263.4	4358.9	4550
SPI	0.24	0.57	0.26	0.58	0.26	0.3

Figure 10 Comparison between AHS, AEC and SPI values of different manufacturers

i. The above stated graph shows the comparative analysis of AHS, AEC and SPI values of different manufacturers for average climate.
ii. It is being observed that the relation between AEC and SPI are directly proportional for most of the manufacturer. However, there is a slight change in one manufacturer in this proportionality.
iii. Considering the manufacturer 2, the value of SPI id high and the AHS value is lesser compared to other manufacturers. This is because the RVU of manufacturer 2 uses recuperative heat exchanger and has a better efficiency than other manufacturers.
iv. Comparing manufacturer 1 and manufacturer 3 it is observed that the SPI values has a lesser change but there is a large change in their AEC values. This is due to the efficiency and the heat exchanger used in the RVU leading to a better rating for manufacturer 1.
v. Comparing manufacturer 4, 5 and 6 all three have the same pattern, as the value of SPI increases the value of AEC increases
vi. The value of AHS has only a small change in it depending upon the kind of heat exchanger used in the RVU's. it is found that the AHS for all the manufacturer has similar values for the Average climatic condition
vii. From the above graph it is interpreted that the value of AEC depends upon the value of SPI which in turn has a major impact on the classification of the RVU. In simple words lesser the value of AHS better the classification.

3.3.4 Comparison between ACE values of different manufacturers for average climate

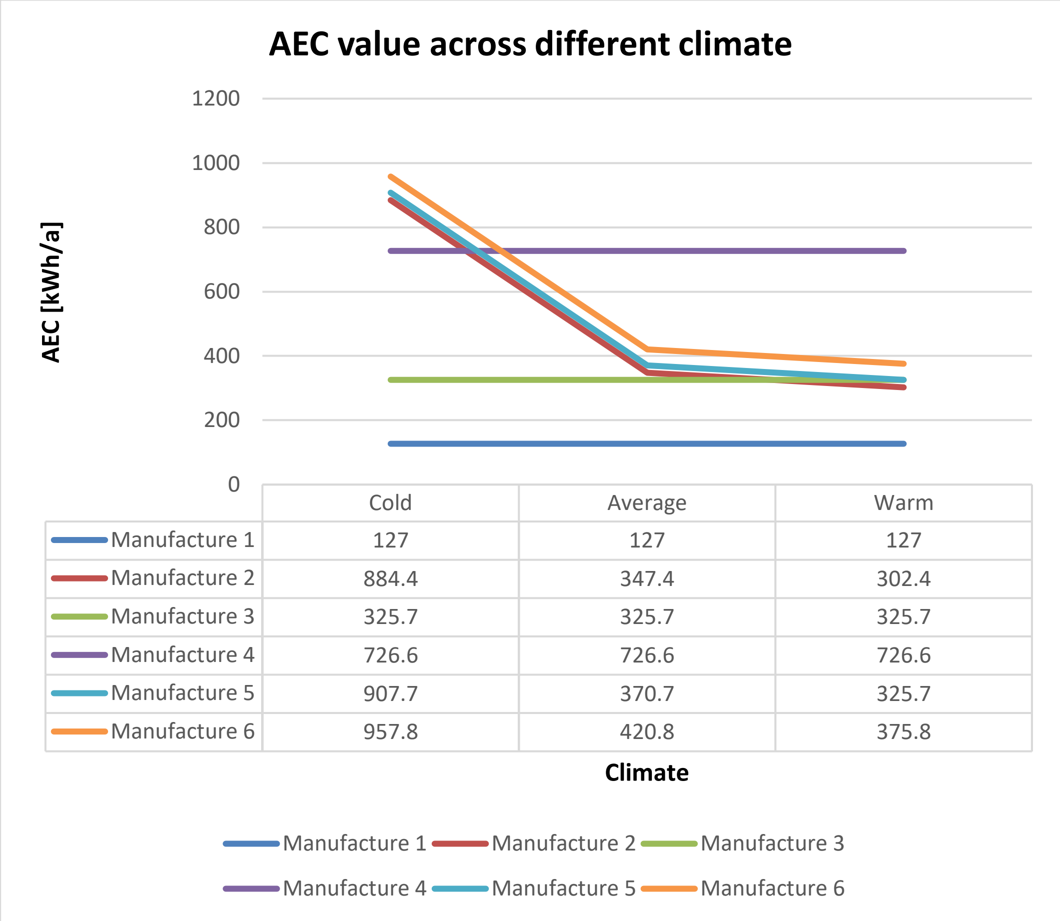


Figure 11 Comparison of AEC across various manufacturers for average climate

i. The above stated graph shows the AEC values of all the manufacturers across average climatic condition.

ii. It is observed that the graph has a similar pattern for set of three manufacturers with high values in cold climate and lower in warm climate and the other three manufacturers has a constant value in all climatic condition

iii. It is observed that the manufacturer 1, 3 and 4 has a constant straight-line graph across all the climatic condition. This is because these three RVU's use regenerative heat exchangers. As the annual heating energy for defrosting in regenerative heat exchanger is zero there by keeping the value of Q_{defr} to zero.

iv. Manufacturers 2, 5 and 6 have a variable AEC values since they all use variable heating values and thus uses recuperative heat exchanger in their RVU's. These three manufacturers have varying value of Q_{defr} for different climates.

v. It can be noted that manufacturer 1 has the lowest value of AEC indicating that it is the best among all others.

vi. Manufacturers 2, 5 and 6 have high values of AEC in cold climate and it is reduced in average and warm climates. But considering manufacturer 4 it has a constant high value of AEC in all climates leading to a poor rating.

vii. From all the above observations it is clear that the AEC value remains constant for RVU's using regenerative heat exchanger and the value of AEC changes along with the climate for RVU's using recuperative heat exchangers.

3.3.5 Comparison between the Energy usage of RVU, Electric Heater and Gas Heater for Average climatic condition

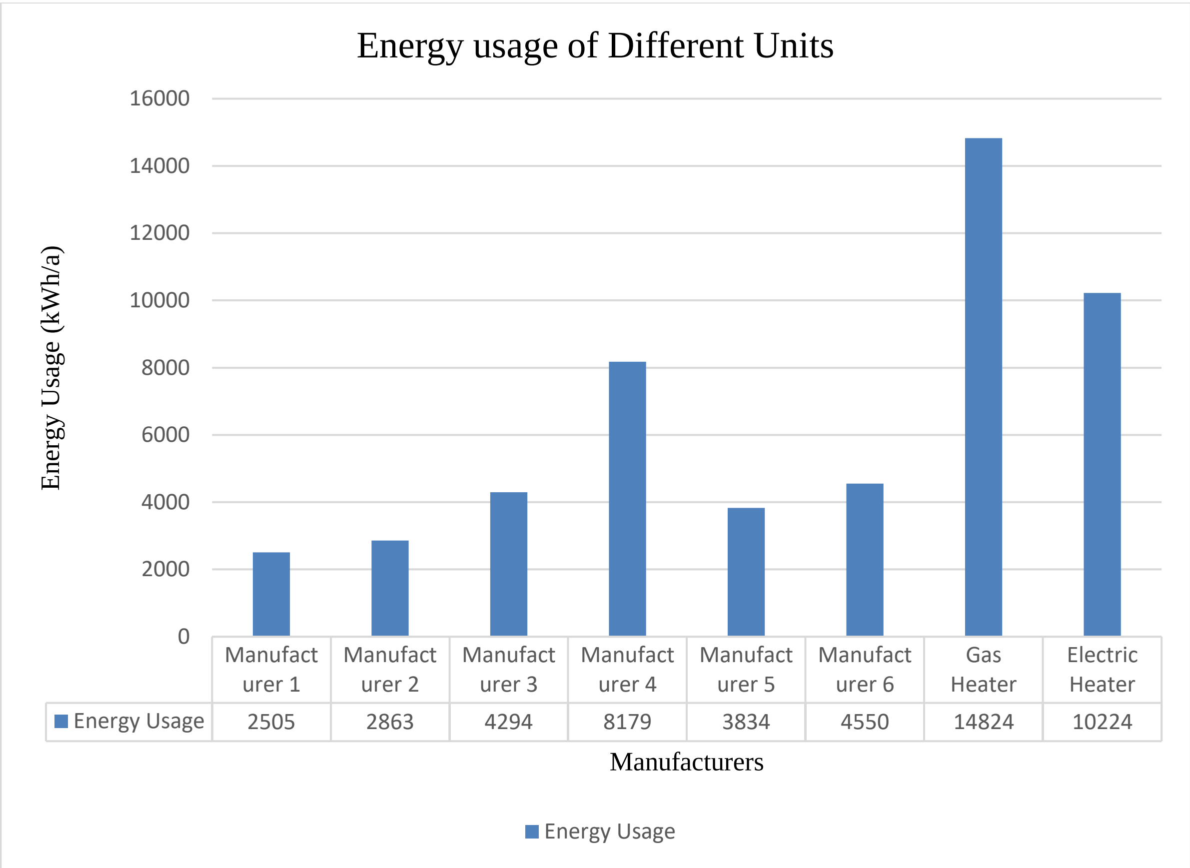


Figure 12 Comparison between AEC of different units

i. The above graph corresponds to the Energy usage values of considered RVU's, gas heater and electrical heater.

ii. Although there is a significant change in energy consumption within RVU's, while comparing them to the conventional heaters they seem to have a slight variation.

iii. It can be observed that the average energy usage of all the manufacturers considered is 29% of the energy used by the gas heaters

iv. It can also be observed that the average energy usage of all the manufacturers considered is 43% of the energy used by the electric heater.

v. This graph clearly explains the advantages of the RVU over the conventional gas and electric heaters.

vi. The cost of operating a gas or an electric heater is very much expensive than the cost of running an RVU because of the energy usage.

vii. From the above observation it can be clearly inferred that the RVU is worth replacing the conventional gas and electric heater.

3.3.6 Comparison between Sound power level and Flow rate of different manufactures

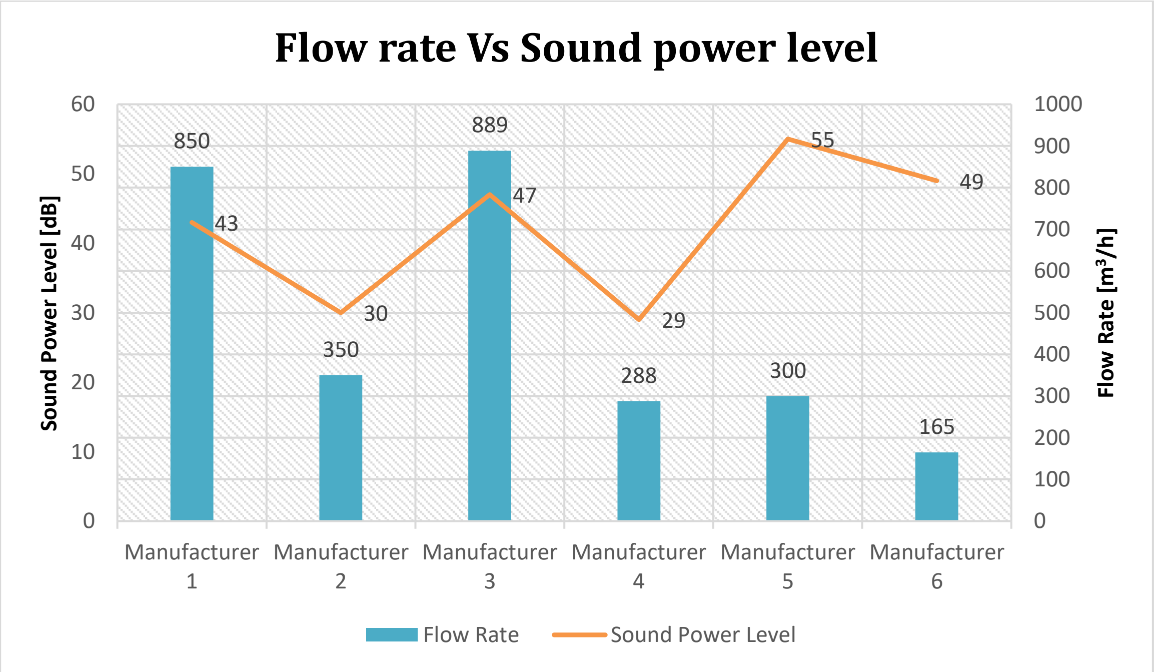


Figure 13 Comparison between Sound power level and Flow rate

i. The above stated graph shows the correspondence of flow rate of the RVU with respect to the sound power level of the RVU.

ii. It can be observed that the graph follows a same pattern except for manufacturers 1 to 4, i.e. the value of the sound power level increases as the value of flow rate increases and vice versa.

iii. For manufacturers 5 and 6 it is observed that the sound power level is high even though their flow rate is low. This is due to the components used in these RVU's make more noise compared to other units

iv. It can be noted that the sound power level of manufacturer 4 is less than other manufacturers. Even though the flow rate of manufacturer is low which is a reason for this low value in sound power level, manufacturer 4 uses a special device in their RVU. This is called as the sound attenuator, which reduces the sound level of the RVU.

v. It can also be noted that a large change in the flow rate has only a small impact on the sound power level of the RVU's of manufacturers 1 to 4.

vi. Even though sound power level has no impact on the rating scale, but the flow rate has some impact on the rating of RVU. SPI of a RVU depends upon the rated power and the flow rate of the RVU.

vii. From the above observations it can be inferred that the flow rate has an impact on the sound power level of the RVU and also sound power level is an important factor for the selection of a particular RVU. The sound power level has no impact n the rating scale.

4. Conclusion

4.1 Conclusion

The main conclusion that is to be inferred from the above results is that, are the traditional gas heaters and electrical space heaters for creating ambient atmosphere inside the residential area worth replacing with the modern RVU’s. This conclusion can be explained by considering of some of the real-life situation and basic comparison from the above results.

For the purpose of comparison, selecting a gas heater and a electrical heater from an online retailer. Consider a gas heater which has an input of about 10000BTU which 2.9 kW (1 kW = 3412.142BTU) [27]. Also consider a electric space heater with an energy consumption of 2000 W which is 2 kW (1 kW = 1000 W) [28]. From the above result, the worst case RVU i.e. manufacturer 4 with a product classification of D is considered.

For a cold climate it is estimated that an average working hour of the residential heating unit is 6552 hours per year as mentioned in “COMMISSION DELEGATED REGULATION (EU) No 1254/2014 of supplementing Directive 2010/30/EU”. So, the energy consumption of the gas and electric heater are 19001 kWh/a and 13104 kWh/a respectively. Whereas the RVU of manufacturer 4 with the rating D has an energy consumption of 11794 kWh/a. which concludes that the RVU of the manufacturer 4 is the most acceptable unit by the consumers as it has the low energy consumption.

For an average climate it is estimated that the average working hour for a residential heating unit is 5112 hours per year as mentioned in “COMMISSION DELEGATED REGULATION (EU) No 1254/2014 of supplementing Directive 2010/30/EU”. As per the above-mentioned hours the gas heater under consideration consumes energy about 14825 kWh/a and the energy consumption of the electric heater under consideration is 10224 kWh/a. The RVU of manufacturer 4 has an energy consumption of 9202 kWh/a for average climate. From the above values it is clear that the worst rated RVU has a lesser AEC compared to the gas and electric heaters.

The capacity of both the conventional heaters and the RVU’s are to the average same. For a 500 sq. ft room it takes the same time for both conventional and RVU to heat up but the input energy given to these units are different. Considering the input energy the RVU’s consumes less energy compared to the conventional heaters.

The price of an RVU may be bit higher than the gas heater and a electrical space heater but it is compensated by the value of the AEC. The average cost for setting up an RVU ranges from 600 USD to 8200 USD (505 EUR to 6911 EUR approx.) [29]. Even though the price of the top class RVU is far higher than the conventional gas heater or an electric space heater, it is worth replacing the conventional units with the modern RVU’s. This conclusion of the replacement is based purely on the AEC value of the gas and electric heater compared to the RVU. The cost and energy spent on gas and electric heaters annually is far more than the energy spent on a RVU.

There is one more category to be considered is the noise. The gas heaters and the electrical space heaters are most likely to produce less noise than an RVU since these gas and electric heaters have no mechanical moving parts and fans in them. Whereas the RVU has an input and output unit which uses fans for the exhaust purpose. The average allowed noise in a residential area is 55 dB as per the “Department of Ecology, State of Washington” [30]. The above analysed 6 manufacturers have the sound power level of less than 55 dB and are suitable for residential ventilation.

Comparing all the results, it can be concluded the most efficient RVU from the above mentioned 6 manufacturers is Manufacturer 1. Manufacturer 1 has a AEC value of 127 kWh/a and the Specific Energy Consumption class of A+ and the Sound Power Level of 43 dB. These values are the most efficient values from the results obtained from all the manufacturers.

Documentary References and Other Sources of Information

[1] Ventilation Architecture, Available online:
https://en.wikipedia.org/wiki/Ventilation_(architecture)

[2] A, Vallati; S, Grignaffinia; M, Romagnaa; L, Maurib; C, Coluccia. – *Influence of Street Canyon's Microclimate on the Energy demand for space cooling and heating of buildings,* Turin, Italy, 2016.

[3] LIDDAMENT, M W – 'A review of ventilation and the quality of ventilation air.', Indoor air, United Kingdom, Volume 10, Issue 3, 2000, pages 193-199.

[4] Tunga Salthammer; Tobias Schripp; Sebastian Wientzek; Michael Wensing. – *Impact of operating wood-burning fireplace ovens on indoor air quality,* Braunschweig, Germany, 2013.

[5] J, Atkinson; Y, Chartier; CL, Pessoa Silva; P, Jensen; Y, Li; WH, Seto. – Natural Ventilation for Infection Control in Health-Care Settings, World Health Organization, Geneva, 2009.

[6] Passive ventilation figure, Available online:
https://passipedia.org/_detail/picopen/ventilation_passive_house.png?id=planning%3Abuilding_services%3Aventilation%3Abasics%3Atypes_of_ventilation

[7] MARTIN Holladay – BLOG ARTICLE: How Much Fresh Air Does Your Home Need?, 2013.

[8] Continuous mechanical extract ventilation figure, Available online:
https://www.practicaldiy.com/self-build/ventilation/continuous-mechanical-extraction.php

[9] Passive stack ventilation figure, Available online:
http://www.greenspec.co.uk/building-design/whole-house-ventilation/

[10] Central ventilation system figure, Available online:
http://build-x.info/ventilation/10033

[11] Ventilation options, Available online:
https://www.homebuilding.co.uk/ventilation-options/

[12] HRV working figure, Available online:
http://www.greenbuildingadvisor.com/articles/dept/green-building-blog/breathe-easy- balanced-ventilation

[13] KLENCK, Thomas – *How it* Works*: Heat Recovery Ventilation*, Online article, 2000.
http://www.popularmechanics.com/home/interior-projects/how-to/a149/1275121/

[14] HRV working, Available online:
https://www.renewableenergyhub.co.uk/heat-recovery-systems-information/how-do-heat-recovery-and-ventilation-systems-work.html

[15] Heat recovery ventilation figure, Available online:
http://www.commercialrenewableenergy.co.uk/heat-recovery/

[16] "COMMISSION DELEGATED REGULATION (EU) No 1254/2014" *supplementing Directive 2010/30/EU of the European Parliament and of the Council with regards to energy labelling of Residential Ventilation Units*, Official Journal C 416, 2016.

[17] Regulation (EU) No 1025/2012 of the European Parliament and of the Council of 25 October 2012 on European standardization, OJ L 316, 2012, p. 12.

[18] Directive 94/9/EC of the European Parliament and of the Council of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres, OJ L 100, 1994, p. 1.

[19] Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC, OJ L 88, 2011, p. 5.

[20] Commission Delegated Regulation (EU) No 65/2014 of 1 October 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of domestic ovens and range hoods, OJ L 29, 2014, p. 1.

[21] Manufacturer 1 product specification, Available online: http://www.komfovent.com/en/product/rhp-800-u-2/?ref=2610

[22] Manufacturer 2 product specification, Available online: http://thomosventilation.en.made-in-china.com/product/pKlnVwPArdhO/China-Thomos-Fresh-Air-Heat-Recovery-Ventilation-System-HVAC-System-THA350-.html

[23] Manufacturer 3 product specification, Available online: http://www.flaktwoods.se/products/air-treatment/air-handling-unit-residential/rdaf/

[24] Manufacturer 4 product specification, Available online: http://www.swegon.com/en/Products/Home-Ventilation/Ventilation-Units/Rotary-heat-exchanger-R-series/CASA-R85-Premium/

[25] Manufacturer 5 product specification, Available online: http://www.titon.co.uk/pages/ventilation-systems/mvhr/h200-q-plus.php

[26] Manufacturer 6 product specification, Available online: http://www.zehnder.co.uk/ventilation-units/heat-recovery-centralised/units-smaller-800-m3h/zehnder-comfoair-160

[27] Manufacture of a gas heater, Available online: https://www.homedepot.com/p/Williams-10-000-BTU-hr-Blue-Flame-Propane-Gas-Heater-with-Automatic-Thermostat-1056511-9/202630658

[28] Manufacturer of a electric space heater, Available online:

https://www.homedepot.com/p/Fahrenheat-2-000-Watt-Small-Room-Wall-Heater-FFC2048/205547086

ANNEX 1 Specific Energy Consumption Classes

SEC classes of residential ventilation units calculated for average climate.

Classification from 1 January 2016 of commission delegated regulation (EU) No 1254/2014

Table 18 SEC classification [16]

SEC Class	**SEC in kWh/a.m^2**
A+	SEC < -42
A	-42 ≤ SEC < -34
B	-34 ≤ SEC < -26
C	-26 ≤ SEC < -23
D	-23 ≤ SEC < -20
E	-20 ≤ SEC < -10
F	-10 ≤ SEC < 0
G	0 ≤ SEC

As per the document presented by the commission delegated regulations (EU) No 1254/2014 of 2016 states that products with a SEC values less than “-42” during its average temperature working time is graded with “A+” classification which is the highest classification rating which can be obtained. And a SEC values of zero and positive number gets the lowest classification i.e. “G”.

ANNEX 2 The Label

a. From 1 January 2016 afterwards marketing for UVUs labelling started.

The label shall provide the following information.

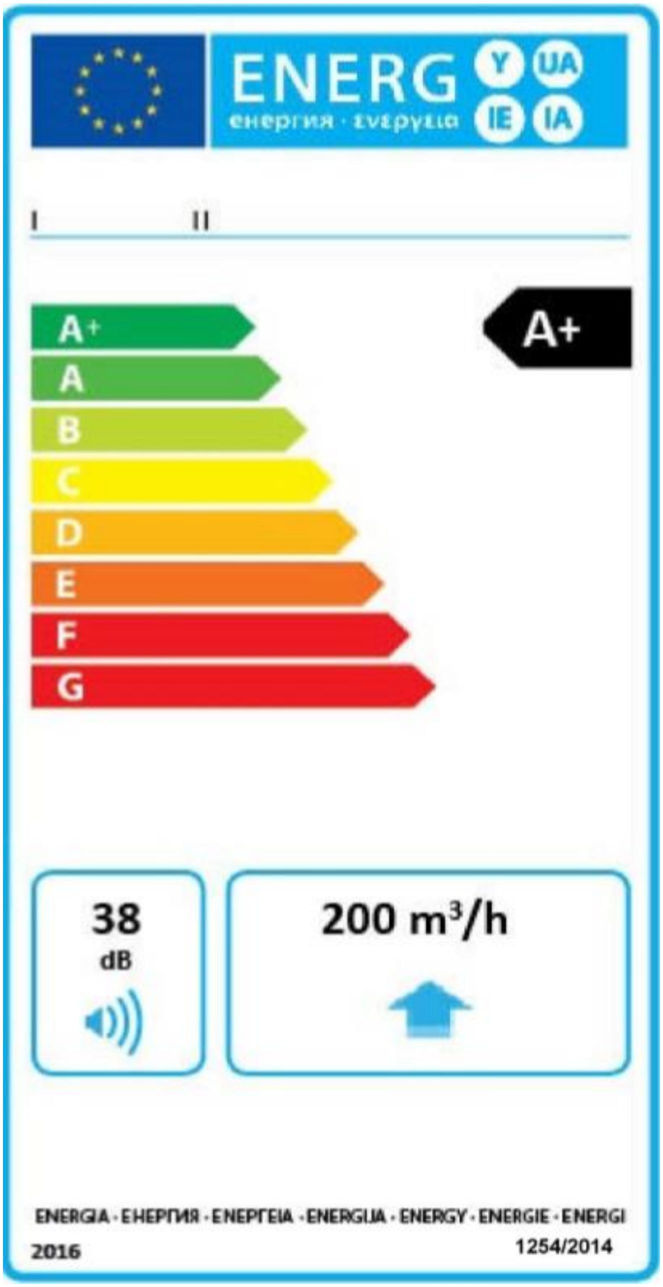


Figure 14 Label for UVUs [16]

1. Suppliers name or trade mark
2. Suppliers model identifier

3. Energy efficiency, head of the arrow containing both of the energy efficiency class of the appliance and relevant energy efficiency class should be at same height.
4. Sound power level rounded to the nearest integer (dB).
5. For representing UVUs, maximum flow rate (m^3/h) is rounded to nearest integer and it should be accompanied by one arrow.

b. From 1 January 2016 afterwards marketing for BVUs labelling started.

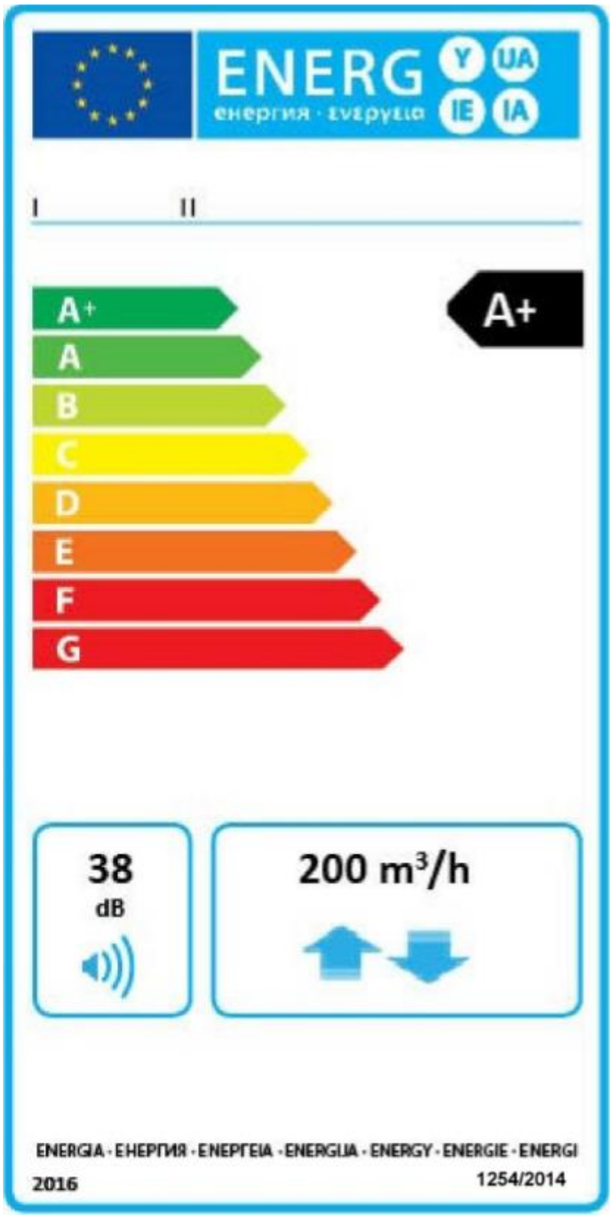


Figure 15 Label for BUVs [16]

The label shall provide the following information.

1. Supplier's name or trade mark.
2. Suppliers model identifier.
3. Energy efficiency, head of the arrow containing both of the energy efficiency class of the appliance and relevant energy efficiency class should be at same height.
4. Sound power level rounded to the nearest integer (dB).
5. For representing UVUs, maximum flow rate (m^3/h) is rounded to nearest integer and it should be accompanied by one arrow.

c. The design of the labels for residential ventilation units shown in points 6.1 and 6.2 shall be as constructed as shown below.

Whereby,

(a) The label dimensions should be atleast 75 mm wide and 150 mm high and printed in a larger formate.
(b) Background should be white.
(c) Colours used are CMYK- cyan, magnenta, yellow and black.
For example, 00-20-00-X: 0% cyan, 20% magnenta ,0% yellow and 100 % black.

Following requirements should be fulfilled by the above shown label (numbers refer to the figure above)

1. **EU label border stroke:** 3.5 pt – Colour: X-00-00-00,
round corners: 2.5mm.
2. EU LOGO: colour: X-80-00-00 and 00-00-X-00.
3. Energy logo: Colour: X-00-00-00.
Pictogram as depicted: EU logo+energy logo: width 62 mm, height 12 mm.
4. Sub-logo border: 1 pt- colour: X-00-00-00, length:62 mm.
5. A+ - G Scales:
- Arrow: height: 6mm, gap 1mm
Colours: A+ class: X-00-X-00
A class: 70-00-X-00

B class: 30-00-X-00

C class: 00-00-X-00

D class: 00-30-X-00

E class: 00-70-X-00

F class: 00-X-X-00

G class: 00-X-X-00

- text: Calibri bold 13 pt, paitals , white

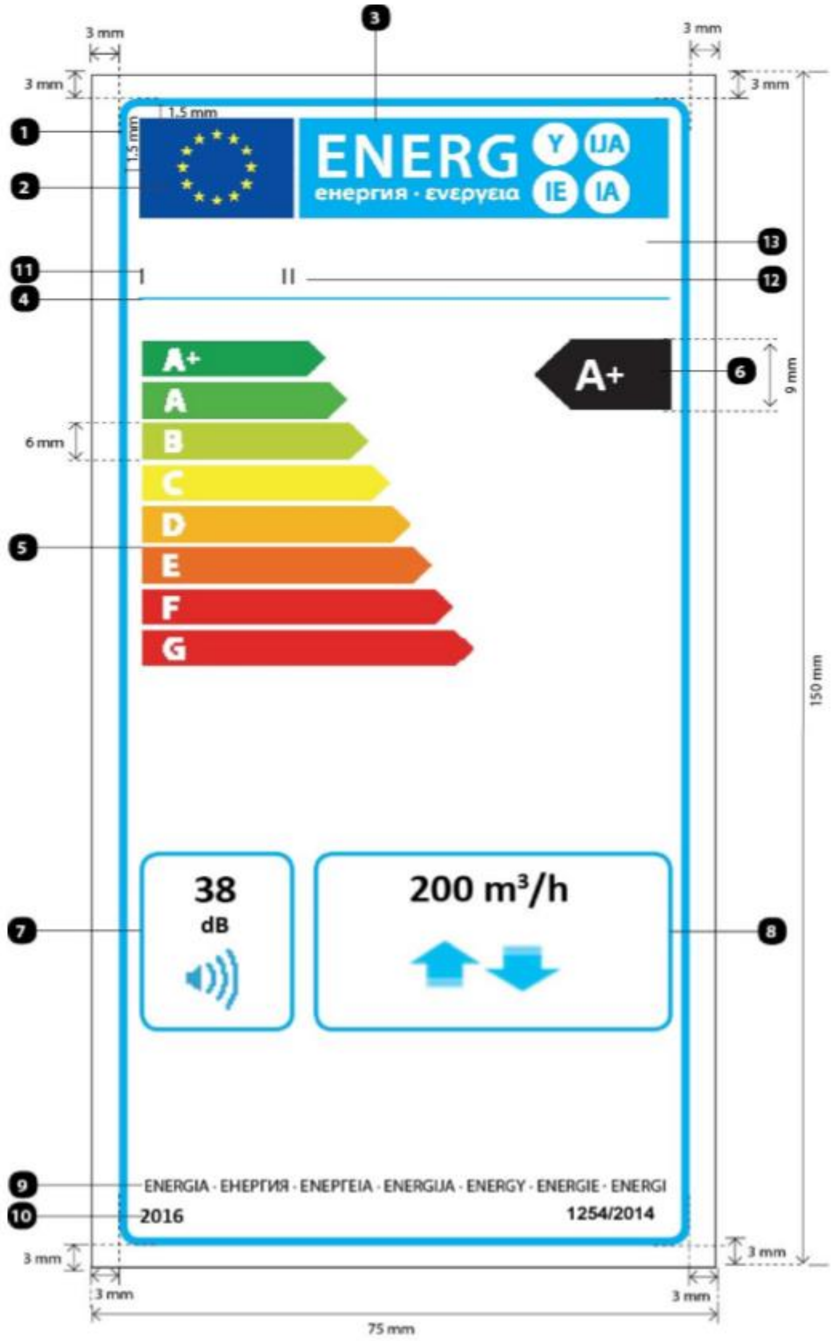


Figure 16 Design of the label for RVUs [16]

6. **SEC class**

   - Arrow: width 17 mm, height: 9 mm, colour: 00-00-00-X

   - text: Calibri bold 18.5 pt, capitals, white, '+' symbols: Calibri bold 11 pt, white aligned on a single row.

7. **Sound power level (dB)**

   -border:1.5 pt, colour:X-00-00-00, round corners: 2.5 mm.

   -value: Calibri bold 16 pt, colour: 00-00-00-X.

   -'dB': Calibri regular 10 pt, colour : 00-00-00-X.

8. **Maximum flow rate (m^3/h)**

   -Border: 1.5pt, colour:X-00-00-00, round corners: 2.5mm.

   -Value: Calibri bold 16 pt, colour: 00-00-00-X.

   -'m^3/h': Calibri bold 16 pt, colour: 00-00-00-X.

   -One or two arrows

   - each width:10mm, each height: 10mm.
   - Colour: X-00-00-00.

9. **Energy**

   - Text: Calibri regular 6pt, capitals, colour:00-00-00-X

10. **Reference period**

    -Text: Calibri bold 8 pt

11. **Supplier's name or trademark**
12. **Supplier's model identifier**
13. Suppliers' name or trademark and model identifier shall fit in a space of 62x10 mm.

ANNEX 3 Technical Documentation

The technical documentation provided with the product should include the following things,

[1] Name and address of the suppliers.
[2] Suppliers model identifiers.
[3] Where appropriate, reference of the standards applied.
[4] Where appropriate, calculation methods, measurement standards, specifications used and technical parameters for measurements.
[5] Overall dimensions and specification of the type of RVU.
[6] SEC class of that model as stated in annex 2 and Sec for each applicable climate zone.
[7] Sound power level in L_{WA}.
[8] Results of the calculations.