Comparative analysis of Heat Valve Ventilation System with Traditional HVAC System in terms of reducing carbon dioxide emission - Case Study GreenHUB House in Aalborg, Denmark

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Abstract

The escalating global demand for energy is an ongoing challenge, and a substantial share of this demand is attributed to the building sector, contributing significantly to worldwide energy consumption. Recent studies have shown that air-based heating system can reduce not only initial but also running costs. Yet, research comparing the environmental impact from the whole life cycle perspective seems to be missing using HVV system in Denmark. This thesis is an comparative analysis between HVV and traditional heating and ventilation methods. Study was performed for a critical apartment case in GreenHUB House building case in Aalborg, Denmark. The paper aimed to investigate in what extent heat valve ventilation compared to traditional heating and ventilation systems can help with reaching the goal of CO_2 emission as low as 2.5kg CO_2 -eq/m^2 /year and ensure comfortable indoor environment specially during heating season. The energy performance of various scenarios including different set points, occupancy profiles and air handling units was conducted. The Simulation was carried out in BSim, while LCA was performed using LCAByg. The results showed that in case of higher set point and choice of air handling unit with higher heat recovery, the HVV system has demonstrated benefits in terms of energy efficiency and reduced environmental impact over traditional system. This led to lower environmental impact using HVV system up to 15% over traditional systems and up to 7% annual energy savings with satisfying indoor environment. The traditional system has showed advantages in energy consumption and environmental impact in other scenarios analysed in the report.

Keywords: IEQ, HVAC, CO_2, HVV, LCA, Air-based heating system, Thermal comfort

Contents

Page

1 Introduction **7**
1.1 Background . . . 7
1.2 Objectives . . . 7

2 Problem describtion **8**
2.1 Problem definition . . . 8
2.2 Research questions . . . 8

3 Literature Review **10**

4 Methology **12**

5 Building Case Description **15**
5.1 Building . . . 15
5.2 Choice of critical apartment . . . 16

6 Project Input **18**
6.1 Thermal Comfort . . . 18
6.2 Heat Demand Calculation . . . 21
6.3 Internal Heat Gains . . . 22
6.4 Moisture Profile . . . 24
6.5 Weather Data . . . 26
6.6 Simulation Input . . . 26
6.7 LCA Input . . . 29

7 Heating and Ventilation Systems **30**
7.1 Traditional Heating and Ventilation Systems . . . 30

8 Heat Valve System **34**
8.1 Theory and Principle of Heat Valve Ventilation System . . . 34
8.2 Manifold design . . . 35
8.3 HVV system calculation . . . 36

9 Strategies Simulations **38**
9.1 Simulation for design temperatures without occupants or heat gains . . . 39
9.2 Simulation with heat and moisture gains . . . 45

10 Comperative analysis **57**
10.1 Set point: 20°C 57
10.2 Setpoint 22 69
10.3 Summary 79

11 Life Cycle Assessment **81**
11.1 Introduction 81
11.2 Results 81
11.3 Conclusion 87

12 Discussion **89**

13 Conclusion **91**

A Appendix A **95**

B Appendix B **102**

C Appendix C **111**

D Appendix D **127**

E Appendix E **140**

List of Figures

4.1 BSim Model 13
4.2 LCAByg 14

5.1 Layout of Critical apartment 17

6.1 Description of the applicability of the categories used 18
6.2 Operative temperature for heating season 19
6.3 Operative temperature for cooling season 20
6.4 Optimum operative temperatures as a function of clothing and activity . . 20
6.5 Internal heat loads for elderly couple 22
6.6 Internal heat loads for elderly couple 23
6.7 Standard moisture production for a family of four. Figure reproduction from soure: [11] 24
6.8 Weekly profile of moisture production for elderly couple 25
6.9 Weekly profile of moisture production for working couple 25
6.10 BSim simulation Systems input part 1 27
6.11 BSim simulation Systems input part 2 28

7.1 Exhausto VEX40T Air Handling Unit 31

8.1 Schematic design of HVV system 34
8.2 Manifold cross section 35
8.3 Manifold design 36

9.1 Mean temperature and number of hours below 20°C throughout the year for Traditional system baseline 41
9.2 Mean temperature and number of hours below 20°C throughout the year for HVV system baseline 42
9.3 Average relative humidity in traditional system baseline 43
9.4 Average relative humidity in HVV system baseline 43
9.5 Mean temperature and number of hours below 20°C throughout the year for Traditional system with ventilation unit without moisture recovery, for elderly couple 46
9.6 Mean temperature and number of hours below 20°C throughout the year for HVV system with ventilation unit without moisture recovery, for elderly couple 47
9.7 Relative humidity for a traditional system for elderly couple 48
9.8 Relative humidity in March for a traditional system with a set point of 22°C 49
9.9 Relative humidity for HVV system for elderly couple 50
9.10 Relative humidity in March for an HVV system with a set point of 22°C . 50
9.11 Mean temperature and number of hours below 20°C throughout the year for Traditional system with ventilation unit without moisture recovery for working couple 53
9.12 Mean temperature and number of hours below 20°C throughout the year for Traditional system with ventilation unit without moisture recovery for working couple 54
9.13 Relative humidity for traditional system for working couple 55
9.14 Relative humidity for the HVV system for working couple 56

10.1 Energy performance of the traditional system and HVV at a set point of 20°C with no heat gains 58
10.2 Mean temperature for traditional and HVV system for 20°C with no heat gains 59
10.3 Moisture levels for traditional and HVV system for 20°C with no heat gains 60
10.4 Energy performance of the traditional system and HVV at 20°C for elderly couple 61
10.5 Mean temperature for traditional and HVV system for 20°C for elderly couple 62
10.6 Moisture levels for traditional and HVV system for 20°C for elderly couple 63
10.7 CO^2 concentration for traditional and HVV system for 20°C for working couple 64
10.8 Energy performance of traditional system and HVV at a set point of 20°C for working couple 65

10.9 Mean temperature for traditional and HVV system for 20°C for working couple . . . 66
10.10 Moisture levels for traditional and HVV system for 20°C for working couple 67
10.11 CO^2 Concentration for traditional and HVV system for 20°C for working couple . . . 68
10.12 Energy performance of traditional system and HVV at set point of 22°C with no heat gains . . . 69
10.13 Mean temperature of traditional system and HVV at set point of 22°C with no heat gains . . . 70
10.14 Moisture levels of traditional system and HVV at set point of 22°C with no heat gains . . . 71
10.15 Energy performance of traditional system and HVV at set point of 22°C for elderly couple . . . 72
10.16 Mean temperature of traditional system and HVV at set point of 22°C for elderly couple . . . 73
10.17 Moisture levels of traditional system and HVV at set point of 22°C for elderly couple . . . 74
10.18 CO^2 concentration of traditional system and HVV at set point of 22°C for elderly couple . . . 75
10.19 Energy performance of traditional system and HVV at set point of 22°C for working couple . . . 76
10.20 Mean temperature of traditional system and HVV at set point of 22°C for working couple . . . 77
10.21 Moisture levels of the traditional system and HVV at set point of 22°C for working couple . . . 78
10.22 CO^2 concentration of traditional system and HVV at set point of 22°C for working couple . . . 79
10.23 Annual Energy Consumption Comparison . . . 80

11.1 LCA results for baseline for set point of 20°C . . . 82
11.2 LCA results for baseline for set point of 22°C . . . 83
11.3 LCA results for elderly couple for set point of 20°C . . . 84
11.4 LCA results for elderly couple for set point of 22°C . . . 85
11.5 LCA results for working couple for set point of 20°C . . . 86
11.6 LCA results for working couple for set point of 22°C . . . 87
11.7 LCA Comparison between scenarios . . . 88

A.1 U-value Calculation of Roof Construction . . . 96
A.2 U-value Calculation of Wall Construction . . . 97
A.3 Linear and Transmission Losses Calculation . . . 98
A.4 Heat Loss calculation from the Kitchen and Living area . . . 99
A.5 Heat Loss calculation from the Bedroom . . . 100
A.6 Heat Loss calculation from the Bathroom . . . 101

B.1 Internal heat loads from people for elderly couple . . . 103
B.2 Internal heat loads from equipment for elderly couple . . . 104

B.3 Internal heat loads from people for working couple 105
B.4 nternal heat loads from equipment for working couple 106
B.5 Hourly schedule of internal heat loads from the bedroom for elderly couple 107
B.6 Hourly schedule of internal heat loads from the Kitchen and Living area for elderly couple 107
B.7 Hourly schedule of internal heat loads from the bedroom for working couple 108
B.8 Hourly schedule of internal heat loads from the Kitchen and Living area for working couple 108
B.9 Heat loads from for various activities and equipment used in the calculation 109
B.10 Moisture production by elderly couple 109
B.11 Moisture production by working couple 109
B.12 Moisture production data from occupants and various sources 110

C.1 Ventilation unit ECO360R temperature and moisture efficiency 111
C.2 Ventilation unit VEX40T temperature efficiency 112
C.3 Render of Traditional Systems 112
C.4 Render of HVV System 112
C.5 Plan of traditional Ventilation System 113
C.6 Plan of HVV System 114
C.7 Heat loss calculations 115
C.8 Heating Demand 116
C.9 Radiators calculations 116
C.10 Ventilation Calculations 116
C.11 Duct material take off - Traditional Ventilation System 117
C.12 Piping material take off - Traditional Heating Sysytem 118
C.13 Duct material take off - HVV System 119
C.14 Pressure Loss of traditional ventilation system calculated by MagiCAD . 120
C.15 Pressure Loss of traditional ventilation system calculated by MagiCAD . 120
C.22 Pressure Loss of HVV system calculated by MagiCAD 120
C.16 Pressure Loss of heating system calculated by MagiCAD 121
C.17 Pressure Loss of heating system calculated by MagiCAD 122
C.18 Pressure Loss of heating system calculated by MagiCAD 123
C.19 Pressure Loss of heating system calculated by MagiCAD 124
C.20 Pressure Loss of heating system calculated by MagiCAD 125
C.21 Pressure Loss of HVV system calculated by MagiCAD 126

E.1 Manifold Calculation from AIACalc Software 141
E.2 Manifold Calculation from AIACalc Software 142
E.3 LCA input table for Traditional System 143
E.4 LCA input table for HVV System 144
E.5 List of materials used for HVV manifold 145
E.6 Drawing of elements used for HVV manifold 146
E.7 List of materials with calculated weight per unit 147
E.8 EDP of Ventilation Unit 148
E.9 EDP of Ventilation Unit 149

List of Tables

5.1 Construction of building components 16

6.1 Heat losses within the apartment 21

7.1 Required supply and extraction airflow 31
7.2 Heat demand for radiators in rooms 32
7.3 Selection of radiators 33

8.1 Heat demand for heated spaces 36
8.2 Heat valve ventilation system airflow requirement 37

9.1 Overview of simulated variants for both sytems 39
9.2 Energy consumption of traditional system with no heat loads 39
9.3 Energy consumption of HVV system with no heat loads 40
9.4 Energy consumption of traditional system with Elderly Couple 45
9.5 Energy consumption of HVV system with Elderly Couple 45
9.6 Energy consumption of traditional system for working couple 52
9.7 Energy consumption of HVV system for working couple 52

Chapter 1

Introduction

1.1 Background

In the European Union, the building stock represents 40% of the overall energy consumption, establishing the building sector as the largest single consumer of energy. [7] Therefore, the need for sustainable and energy-efficient building solutions has become compulsory in the face of climate change and rising energy costs. Simultaneously, there is significant emphasis on indoor climate and health conditions. These aspects, together with the overall objective of achieving fossil fuel independence in Denmark are key factors behind quality building. [1] To achieve that and ensure occupants' comfort and well-being and minimize environmental impact innovative design principles and technologies must be applied. Heating and ventilation systems play a major role in achieving these goals. They have a direct influence on cost, energy performance, climate impact, and CO_2 emissions. The design of a building's HVAC system is crucial as it directly influences carbon emissions during both the production and operational phases. Methods such as such as radiators, boilers, etc. have been reliable for years. Although, these systems' performance is not necessarily in line with ideas of modern sustainability. Air-based heating systems, on the other hand, have come to light as an alternative that shows promise in terms of giving increased efficiency and decreased environmental effects. Therefore, is crucial to critically assess the benefits and downsides of both conventional and air heating systems in modern building contexts as the focus of the globe shifts towards lowering greenhouse gas emissions and energy consumption. To ensure, that new methods are more sustainable than traditional methods, Life Cycle Analysis (LCA) is used for evaluating the environmental impact of those systems.

1.2 Objectives

The choice of heating system in a modern building is a complex decision that must be made carefully and consider factors such as initial costs to long-term, energy performance, climate impact, and CO_2 emissions. The following paper focuses on the implementation of the newly developed heat valve ventilation system (HVV) that combines both heating and ventilation systems into one unit.

Chapter 2

Problem describtion

2.1 Problem definition

It has been highlighted in the previous chapter that the building sector plays a significant role in global CO_2 emissions. According to the National Strategy for Sustainable Construction threshold requirement for new construction will be 7,5 kg CO_2 -eq/m^2 /year by 2029. [5] However, the ambitious goal for the GreenHUB House project is to reach the CO2 emission of 2,5 kg CO_2 -eq/m^2 /year.

2.2 Research questions

Therefore, this project aims to investigate to what extent heat valve ventilation compared to traditional heating and ventilation systems can help with reaching the goal of CO_2 emission as low as 2.5 kg CO_2 -eq/m^2 /year and how it influences the thermal comfort and indoor air quality? To help answer the problem statement this research will address the following key research questions:

- *What is the energy performance of air heating systems compared to traditional heating systems? How do they influence overall energy consumption over the year and heating/cooling loads in modern buildings?*

- *Does the heat valve system ensure a comfortable Indoor Air Environment for occupants?*

- *Can the adoption of Heat Valve Ventilation systems in modern buildings reduce CO2 emission, meet the goal of the limit of 2.5 kg CO_2 -eq/m^2 /year?*

The paper analyses various scenarios, comparing conventional systems with newly developed HVV system which aims to reduce CO_2 emission and ensure comfortable indoor quality. The objective of this research is to help stakeholders in the selection of the systems for modern residential buildings by performing a comparative analysis.

2.2.1 Delimitation

This research is focused on the comparative analysis of two systems, with a primary focus on energy efficiency and environmental impact through the life cycle of the building. It is essential to define the scope and limitations of this study to provide a better understanding of the boundaries. The simulation is specifically limited to investigating and analyzing dynamics related to energy consumption and indoor environmental factors during the heating season. The study does not focus on selection of materials and construction. The assumptions of that have been made and serve only as a baseline. This exclusion allows the study to focus on the specific aspects of two systems, prioritizing energy efficiency and CO_2 emissions. Furthermore, systems are only variable in all scenarios, hence e.g., change of material will influence both scenarios in the same way. Some factors are solely dependent on selected construction e.g., pollution from materials and it is not the scope of this work. Moreover, this study is limited only to the critical apartment that has been selected based on criteria described in Chapter 5.2 and not the whole building. The simulation tool used in this study enables the analysis of CO_2 levels and moisture levels within indoor spaces. Nevertheless, it is important to note that some aspects, such as acoustic performance or air filtration, are excluded due to the limitations of selected simulation software. It should be noted that the findings are based on simulation which depends on the simulated conditions and variables such as weather data.

Chapter 3

Literature Review

The environmental impact of energy consumption and greenhouse gas emissions has become a critical concern worldwide and has been well-researched. According to *Energy renovation of buildings* [4] almost 40% of global energy consumption is assigned to the building sector which makes them a crucial and encouraging center of attention in the field of sustainable transition. [4]

The Danish government, in its comprehensive 2050 strategy to eliminate reliance on fossil fuels in the energy sector, highlights the significance of enhancing the energy performance of the building sector. The strategy emphasizes the implementation of cost-effective measures to reduce energy consumption, aligning with the ambitious goals set for 2050. [2] Residential and transport sectors stand out as the main contributors to the total energy consumption by end-users in Denmark, with residential accounting for 33% in 2019. Heating and ventilation systems in both residential and commercial buildings contribute significantly to energy consumption and carbon dioxide production in Europe. Therefore, promoting energy efficiency in buildings is essential to achieve these goals.[6] Out of all building services, HVAC systems play a significant role in building energy consumption. [9] [13] Moreover, around 25% of energy consumption is dedicated to space heating and hot water production in buildings in Denmark. [4] Incorporating energy-efficient HVAC solutions in buildings plays a crucial role in meeting both local and global targets for reducing carbon dioxide emissions. [13]

Furthermore, research performed by *Pérez-Lombard Et al.* [13] investigated that with the advancement of technology, heating, and ventilation can introduce significant improvements in energy efficiency. Innovations such as the usage of renewable energy sources, relying on hybrid ventilation, or the development of control strategies that effectively ensure acceptable indoor climate quality while reducing energy consumption.

One specific area of focus in terms of energy-efficient solutions is air-based heating systems. Studies have highlighted the efficiency benefits linked to these systems. These recent studies have begun to provide insight into how air-based heating systems can reduce energy consumption and contribute to CO_2 reduction.

While general studies have offered valuable insights into carbon dioxide problems in the building sector, this research specifically focuses on a Heat Valve Ventilation system. For example, in a study conducted by *Rahnama, Samira Et al.* [14] full-scale prototype of this air-based heating novel system was evaluated. According to their findings, air as a medium for heating spaces offers a range of benefits such as quick response time, and increased control by adjusting air flow rate and temperature in individual rooms within a dwelling. [14] Additionally, they emphasized that the integrated system eliminates the need for separate heating and cooling systems, leading to a reduction in both investment and operational costs.

According to studies performed by *Polak, Joanna* [12] where laboratory investigation of HVV was conducted, it was discovered that the system successfully maintained comfortable indoor temperatures. In this work, it was suggested that the system is suitable for residential buildings with low heat demand, where heat losses can be effectively compensated by solar and internal gains.

The existing research on air-based heating systems, particularly their application in Denmark, is limited. There is a lack of comprehensive studies and available literature on Heat Valve Ventilation systems. The available literature on HVV primarily consists of laboratory experiments, especially on room-level and short-term applications. This means that there is relatively little knowledge about how that system performs in the long term on the apartment level.

In conclusion, this literature review provides an understanding of the environmental impact of energy-efficient heating and ventilation systems in buildings. Previous research indicates that HVV systems are promising in terms of efficiency and energy consumption, but there is still room for more research with a life cycle perspective added.

Chapter 4

Methology

This Master Thesis aims to design and evaluate two different systems' solutions in the context of CO_2 emission, as well as their influence on the IAQ and thermal comfort in the rooms. This chapter explains the decisions made and the method used to obtain the necessary data.

The project was started with the analysis of the documentation that was received. First, the Green Hub House Bygherreprogram from Himmerland Boligforening was analyzed. This document provided information about the project, such as the size of apartments, types of materials used for construction, or different systems solutions that are considered to be implemented in this building case. Another relevant document was "Description of the Heat Valve Ventilation (HVV) System in a Green Hub House" which helped with a general understanding of the HVV system. The last document that was analyzed was the Green Hub House Sketchbook from C.F Moller where the location of the apartments concerning the world directions was graphically described.

After completing the examination of the provided documentation, the critical apartment was selected. Then, a simple model was created in Revit to visualize its layout as well as find the needed areas of different building components. Moreover, the precise construction of each of those components was decided according to the project description. Additionally, based on the Revit model, the geometry of the apartment was created in BSim. This model was later used for the evaluation of the systems.

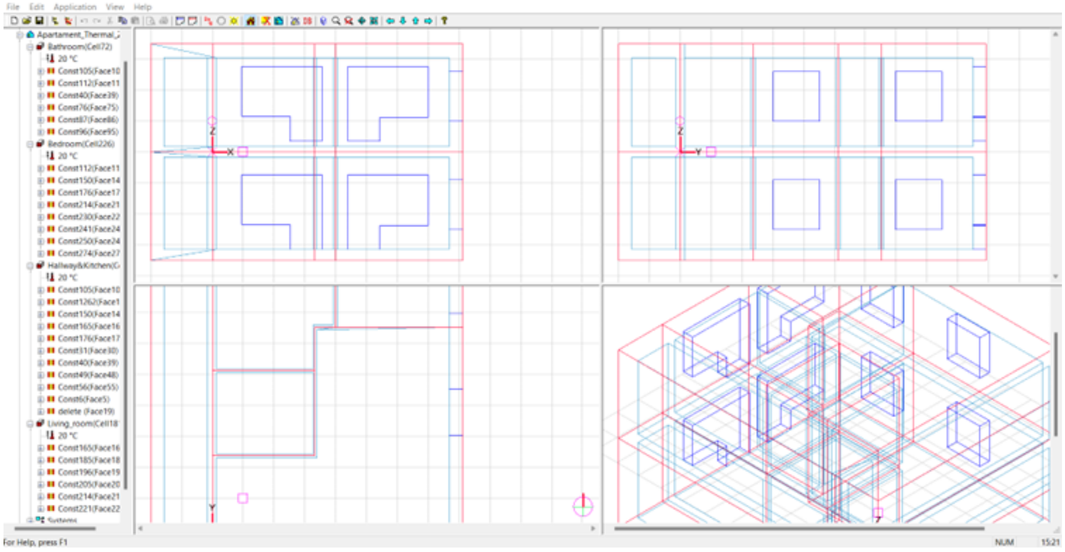


Figure 4.1: BSim Model

When all the relevant decisions were made, the traditional HVAC system was designed. It started with designing a mechanical ventilation system. The airflow needed for the apartment was determined following Building Regulations' requirements to achieve balanced ventilation. Then, the unit that matches the required airflow was selected and the size of the pipes was calculated with the use of MagiCad software. Then the traditional radiator heating system was designed. First, the transmission heat loss for decided before construction was calculated. Together with the ventilation losses and linear losses the heat demand for each room was calculated. All of the heat losses were calculated for the design temperatures set in DS418.

Then, the number of radiators for each room was decided. Based on this decision and the required heat demand for the rooms, the heating output of each radiator was determined. To do it the data sheet of the producer was used. As a last step, the piping was calculated with the use of MagiCAD

Next, the HVV system was designed. For this case, first, the design was done for the same heat demand as the traditional heating system, so comparing of the systems for the same conditions could be done. Morover, the heating coil was dimensioned for the needs of the project.

When both of the systems were designed, the simulations in BSim were made. To compare the traditional system and HVV the simulations were led for the same conditions like people loads, equipment loads, moisture loads, etc. Also, the same ventilation unit was used in both systems with adjustment of heat and moisture recovery for the actual air flow rate.

An important aspect to evaluate was the influence of the systems on indoor climate. To complete that the results from simulations done in BSim were used.

First, the systems were compared in energy performance which included energy use for the heating and the ventilation fan power.

Next, thermal comfort was checked as it is important in the context of the heating system. To determine the temperature range that is considered as comfortable the ISO

7730 was used and then compared with BSim results.

Then, two aspects of Indoor Air Quality were evaluated, these were CO2 and moisture level. This was done according to the requirements from DS 16798.

The main focus of this Thesis was the CO_2 emission of the systems throughout their life cycle. As mentioned in previous chapters, the goal for the GreenHUB project is to reach the CO_2 emission as low as 2.5 kg CO_2 -eq/m^2 /year. This project was checking if the implementation of HVV instead of traditional HVAC can help with reducing emissions. To evaluate this the LCA analysis for the compared systems was done with the use of the LCAByg. As the main focus of the paper is systems it was decided to omit the building construction in LCA calculations to receive clear results only for the systems.

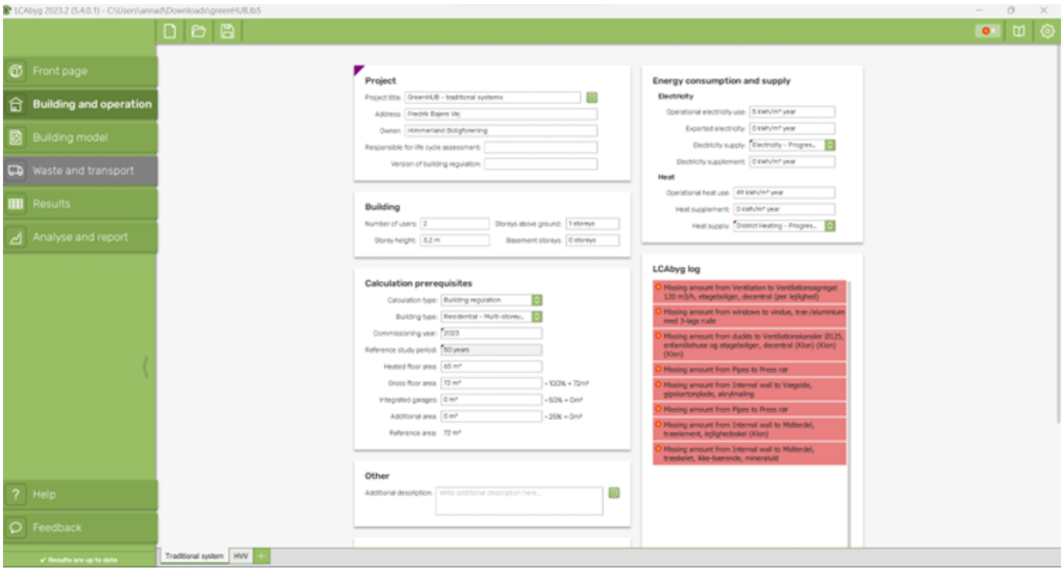


Figure 4.2: LCAByg

As the last step, the results from performed BSim simulations and LCA calculations were compared in the context of both CO2 emission and influance on the mentioned aspects of energy and indoor climate.

Chapter 5

Building Case Description

5.1 Building

The building for the study case is a multi-story residential building with a total area of 4057 m^2. The building will have two to four stories with apartment units. Additionally, it is planned that the ground floor will be used for common spaces, laundry rooms, shops, restaurants, cultural institutions, etc. The building will be located at the Aalborg University Campus on Fredrik Bajers Vej. The building will be heated with district heating at a low temperature (40 °C) through a mixing loop after the district heating connection.

The project is still in the early stages, so the final layout of apartments or construction is not known yet. However, based on information provided by C.F Møler in their most recent planning presentation some decision was made for use of this study case.

It is planned to design two different types of apartments. In both cases, it will consist of a living room with an open-space kitchen, one bedroom, and a bathroom. The area of the apartments will be approximately 57m^2 for the first type and 65m^2 for the second one. As it was mentioned the apartments are not designed yet, however, in the documentation, there is a reference apartment layer which is from the project called “Alfa by Living” from Irmabyen in Rodorve.

When it comes to construction the initial idea is to use bio-based materials. For this study case, it was decided to use wooden lightweight construction for the construction of walls, story partitions, and roof. In the table below all mentioned constructions are listed.

Building component	Construction	Thickness	U-value W/m2K¿W/m2K
Roof	Gypsum board	0.026	0.120
	Battens w/insulation	0.045	
	Rafters with insulation	0.3	
	Ventilated cavity	0.05	
	Playwood board	0.018	
	Waterproof covering	0.005	
Wall	Gypsum board	0.016	0.156
	Vapor control layer	0.001	
	Studs w/insulation	0.25	
	OSB board	0.018	
	Ventilated cavity	0.05	
	Brick	0.108	
Storey partition	Gypsum board	0.026	
	Joints w/insulation	0.3	
	Playwood	0.018	
	Wooden flooring	0.015	
Partition walls	Gypsum board	0.016	
	Studs/w insulation	0.1	
	Cavity	0.05	
	Studs w/insulation	0.1	
	Gypsum board	0.016	
Windows	Energy class A		
	3 layers glass		
	Transmission coefficient (Uw) - 0.79 W/m2K		
	Solar transmittance (Gg) – 0.42		
	Glazing part (Ff) – 0.79		
	Light transmittance (Lt) - 0.		

Table 5.1: Construction of building components

5.2 Choice of critical apartment

The selection of critical apartments within the building was selected based on factors like orientation, sun exposure, orientation of windows, and floor level. The apartment was selected as the one with the most heat losses. The selected apartment is facing northeast with balconies and windows oriented in this direction; thus apartment has the smallest solar gains. Moreover, the apartment is located on the top floor which generally experiences more transmission loss through the roof construction and less heat coming from neighboring apartments.

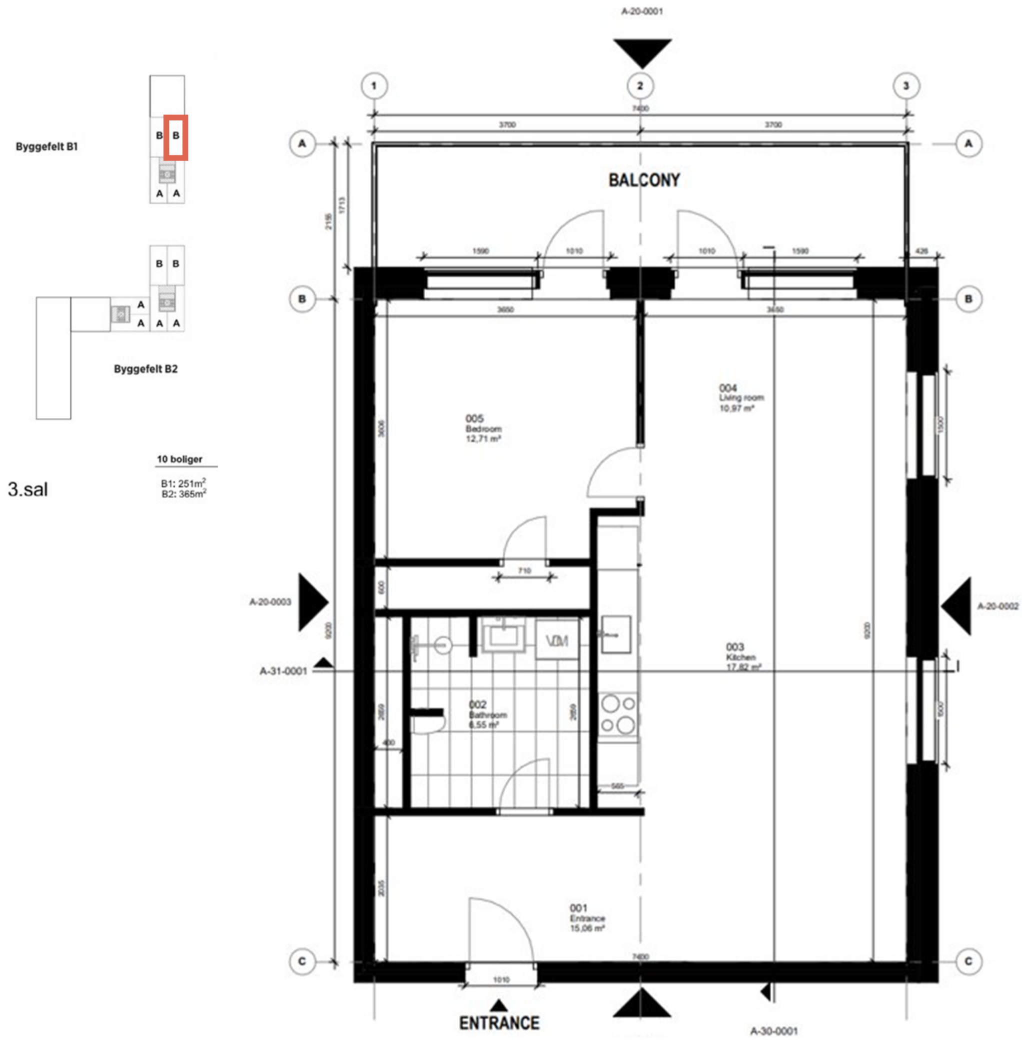


Figure 5.1: Layout of Critical apartment

Chapter 6

Project Input

In this chapter, the input of this project will be presented. As it was mentioned before the project is in the early stage of design consequently the part of the project will be based on assumptions.

6.1 Thermal Comfort

To assess the thermal comfort of the apartment it was necessary to assume and calculate a few factors. First, the category of the building, for which the recommended values were taken, was determined. According to ISO 15251, as shown in Figure 6.1 the apartment building is Category II. In other standards, the naming of the categories might be different, in ISO 7730 Category II will be corresponding to Category B.

Table 1 — Description of the applicability of the categories used

Category	Explanation
I	High level of expectation and is recommended for spaces occupied by very sensitive and fragile persons with special requirements like handicapped, sick, very young children and elderly persons
II	Normal level of expectation and should be used for new buildings and renovations
III	An acceptable, moderate level of expectation and may be used for existing buildings
IV	Values outside the criteria for the above categories. This category should only be accepted for a limited part of the year

Figure 6.1: Description of the applicability of the categories used

Next, it was needed to determine the activity level and clothing level of the people living in the apartment. It was done according to the ISO 7730. Occupants will have different activities during the day, however, it was assumed that most of the time people are relaxing or studying, which corresponds to an activity level between 1-1.2 met. For this case, the activity level of 1.2 met will be used for further calculations. When it comes to the clothing level, it was decided to divide it into two seasons – heating and cooling and use the standard level which is 1.0 clo and 0.5 clo respectively.

Based on these decisions, the operative temperature for heating and cooling seasons was determined with the use of diagrams of Optimum operative temperature as a function of clothing and activity from ISO 7730. As visible in figure6.2 for the heating season the optimal operative temperature is 22°C with range of +/-2°C and in figure 6.3 for the cooling season it is 25°C with range of +/- 1.5°C.

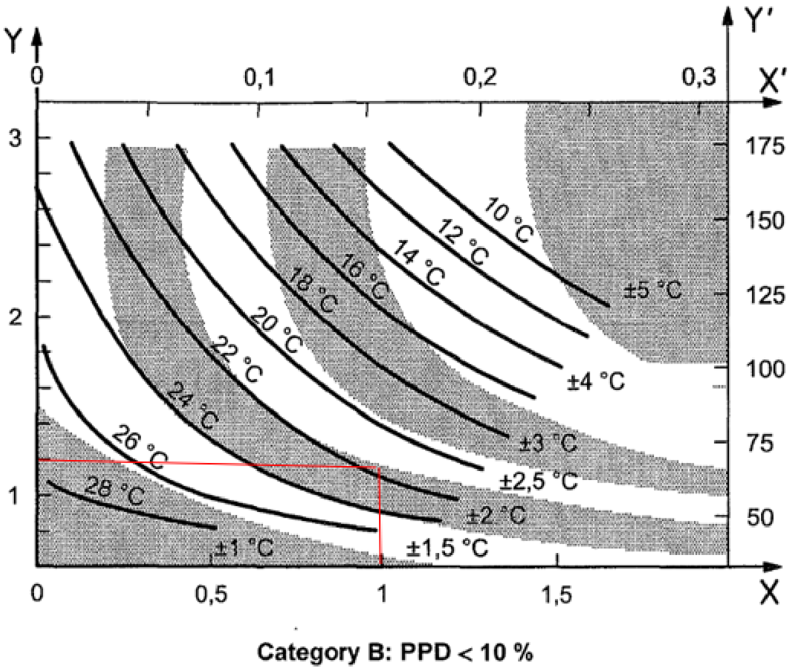


Figure 6.2: Operative temperature for heating season

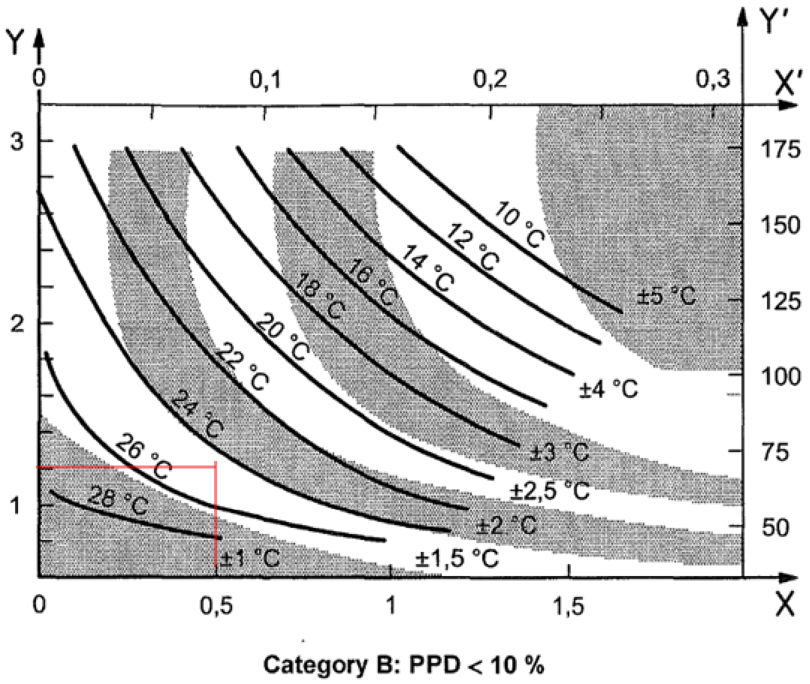


Figure 6.3: Operative temperature for cooling season

The diagrams also show the range around the optimum temperature for the three categories.

Key

PPD predicted percentage dissatisfied, %

X basic clothing insulation, in clothing units, (clo)

X′ basic clothing insulation, in clothing units, $m^2 \cdot °C/W$

Y metabolic rate, in metabolic units, (met)

Y′ metabolic rate, in metabolic units, W/m^2

Figure A.1 — Optimum operative temperature as function of clothing and activity

Figure 6.4: Optimum operative temperatures as a function of clothing and activity

6.2 Heat Demand Calculation

The first phase of the investigation involved calculating heat demand which consists of linear losses, transmission losses, and ventilation losses. [3] The heat losses do not include transmission losses from the floor construction since the apartment is located on the last floor of the building and there is an apartment below. Table 6.1 shows the heat losses from each zone of the apartment. Calculations were done according to DS 418:2011 + Till.1:2020 for design temperature -12°C as a critical temperature during winter time. The comprehensive calculations are available in the appendix A

Room	Transmission loss [W]	Ventilation loss [W]	Linear loss [W]	Total [W]
Living room / kitchen	608.6	63.6	0	672.3
Bedroom	231,6	18.45	0	250.1
Bathroom	33.4	0	0	33.4
				948.34

Table 6.1: Heat losses within the apartment

6.3 Internal Heat Gains

In the next phase of the investigation, heat gains from occupants and equipment were added. This strategy takes into consideration different occupancy profiles and recognizes the dynamic nature of the real-world scenarios, where additional factors contribute to the heat balance within the apartment. The figures below are visual representations of the heat gains over a day and a week from occupants and equipment. There are two scenarios: one where an elderly couple spends most of the time at home, and another where a working couple is mostly away from home. Profiles were created for both scenarios across two apartment zones: the bedroom and the living area with the kitchen. Figure 6.5 showcases internal heat loads for an elderly couple in the bedroom. The left axis and stacked column chart represent the total heat gains over the day, while the linear chart and the right axis represent the hourly heat gains.

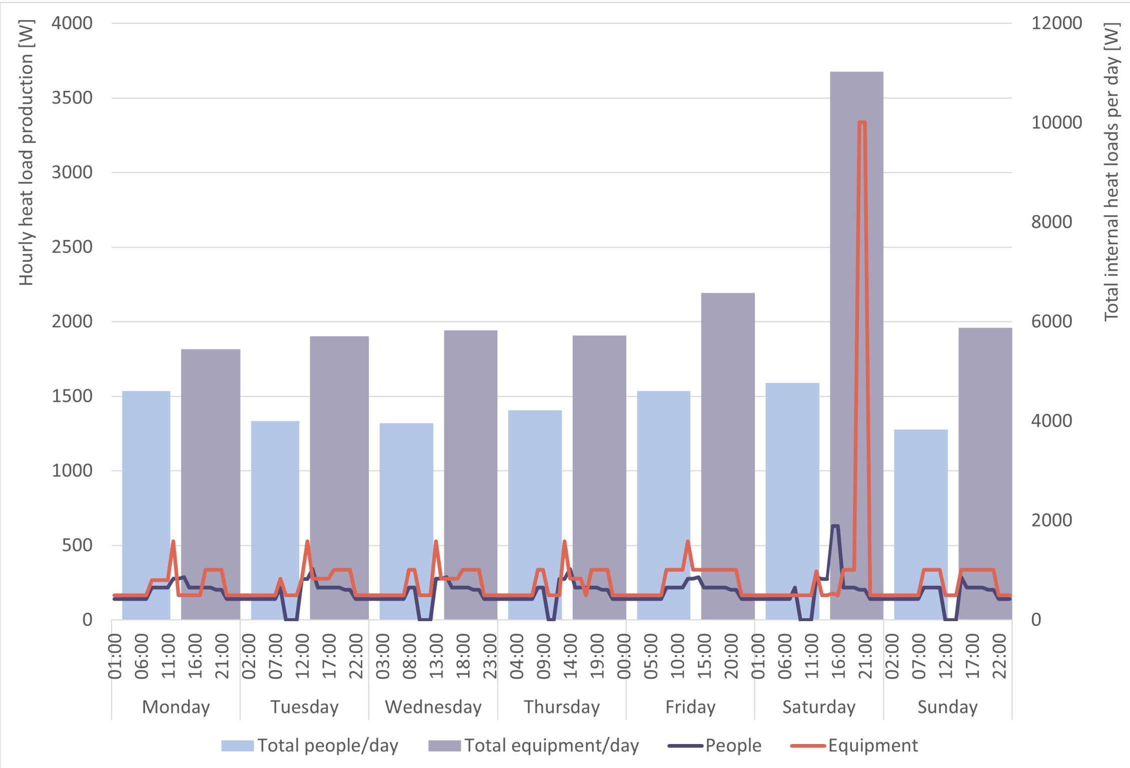


Figure 6.5: Internal heat loads for elderly couple

In figure 6.6, it can be seen that in the scenario involving a working couple, the total heat loads during the day are significantly lower compared to the case with an elderly couple.

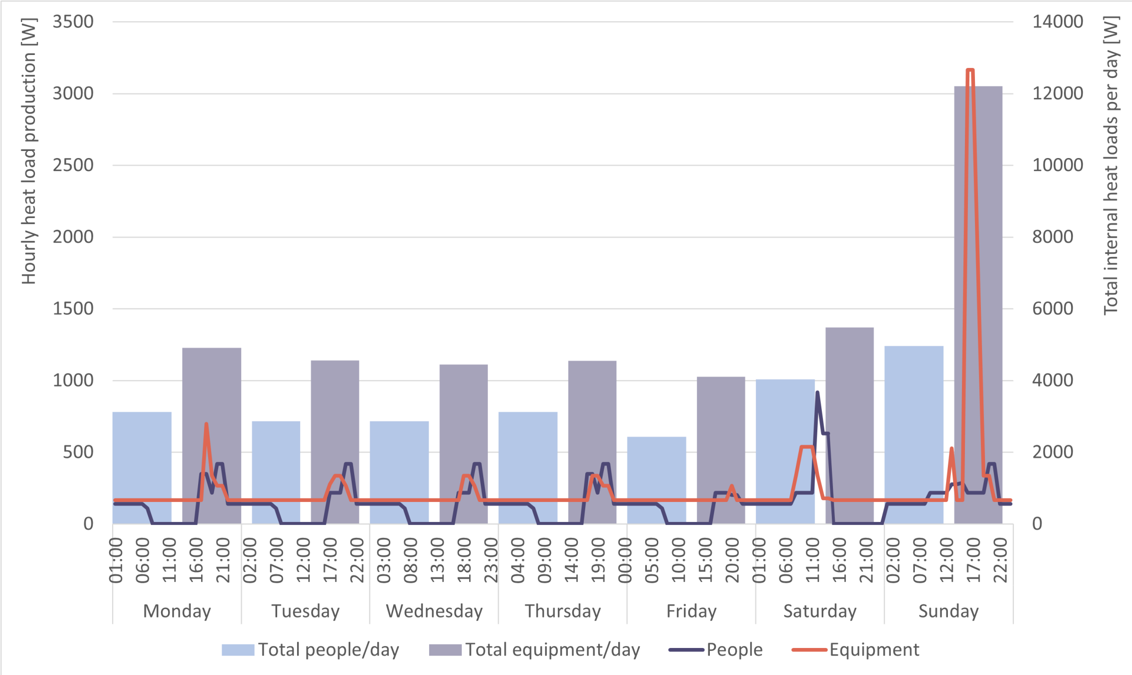


Figure 6.6: Internal heat loads for elderly couple

Based on a weekly schedule, hourly average heat gains for each category over the entire week were calculated. Subsequently, these values were input into the BSim software, and a new schedule was generated to align with the occupancy schedule. Detailed hourly schedules of heating gains for both scenarios can be found in Appendix B.

6.4 Moisture Profile

In the investigation of the moisture profile within an apartment, it was found that four individuals, their activities, and the equipment used typically produce 10.43 kg of moisture per day. [11] Figure 6.7 is reproduction of profile found in [11].

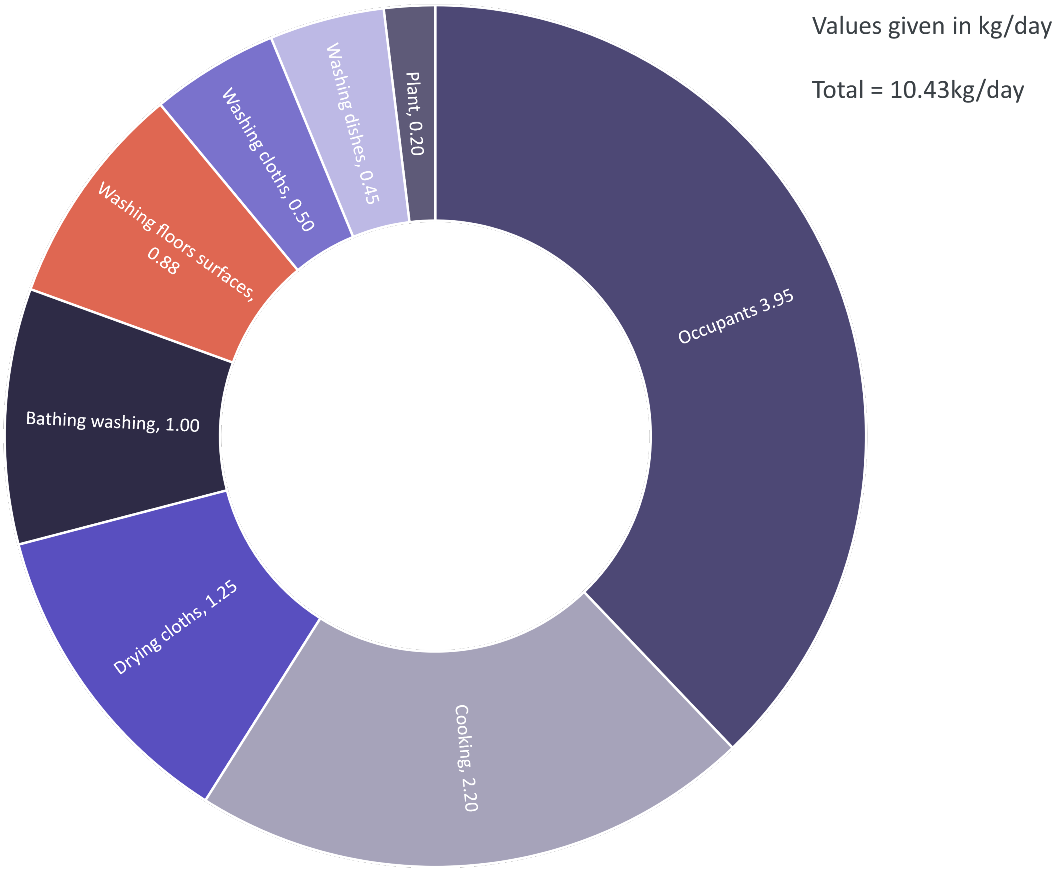


Figure 6.7: Standard moisture production for a family of four. Figure reproduction from soure: [11]

To adjust this information to the specifics of this project, the total amount of daily moisture production was divided between the individuals, resulting in an hourly production per person. According to [18] occupants who remain indoors throughout the day, such as retired couples, will generate higher levels of moisture compared to e.g., working couples. Therefore, moisture profiles were calculated according to occupancy profiles and figures profile elder and present the weekly profile. Complete calculations can be found in the Appendix

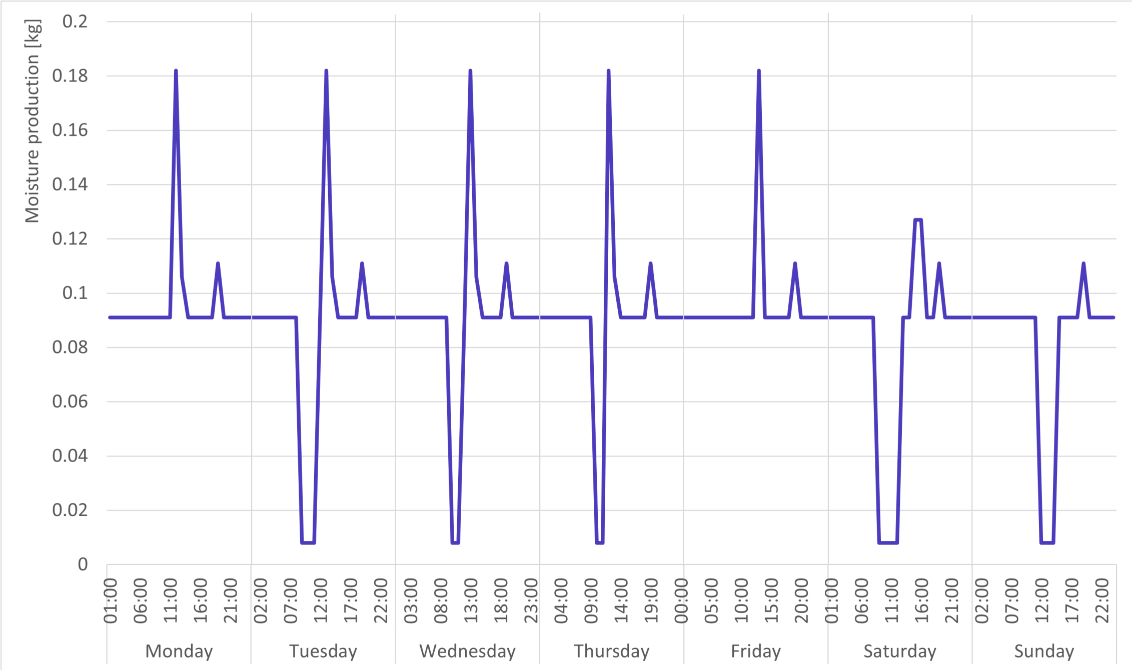


Figure 6.8: Weekly profile of moisture production for elderly couple

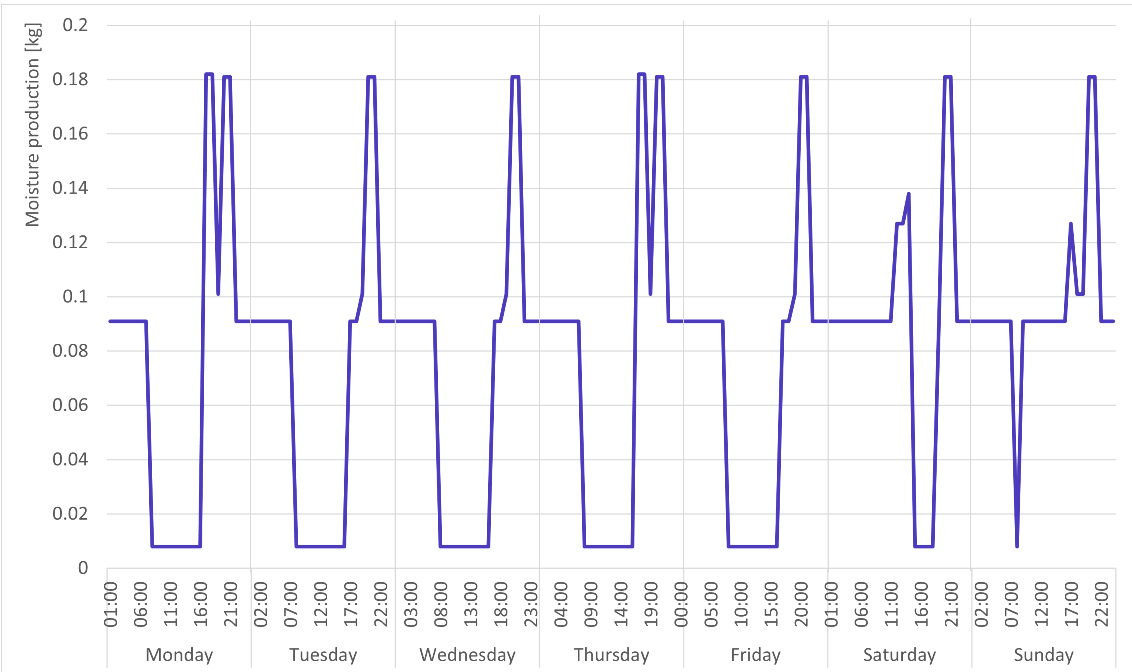


Figure 6.9: Weekly profile of moisture production for working couple

6.5 Weather Data

The weather data employed in the simulation is the “2013 Design Reference Year” (2013DRY)” while the simulation period corresponds to the year 2022. Utilizing weather data from the year 2013 may not fully reflect current atmospheric conditions. Weather patterns and climate conditions, change over time, leading to e.g., rising temperatures in Denmark, due to the phenomenon of global warming.[10] It should be noted, that those limitations should be considered when interpreting the simulated results. For more precise results more recent weather data would be necessary, however, it is currently unavailable.

6.6 Simulation Input

The table below was created to illustrate the input data that was used in the simulation. The first part of the table focuses on the essentials – the influence of people, equipment, and moisture. These factors are not constant, and they change based on the occupancy profiles. For each situation we simulate, the table details the varying loads and moisture generated by residents. In the baseline there are no people present in the apartment, therefore there is no loads in that section. Next, some elements remain constant in all scenarios, where the table presents input data for infiltration, lightning, and venting. Moving forward, the table introduces two systems, each with its own set of variables. First, there is a traditional system where input data is presented for classic heating systems and mechanical ventilation systems. Then, there is the HVV system, heat is delivered by a ventilation system produced by a manifold, and in the simulation input, this component is designated as a heating coil. In both systems, there are two variants of the chosen air-handling ventilation unit. The classic unit with relatively high heat recovery and the alternative unit focuses on moisture recovery, while sacrificing some heat recovery efficiency.

<table>
<tr><th rowspan="2">System</th><th rowspan="2" colspan="2">Description</th><th colspan="2">(Schedule)</th></tr>
<tr><th>Control</th><th>Indication of time</th></tr>
<tr><td colspan="5">No load</td></tr>
<tr><td>Human load</td><td colspan="2">-</td><td>-</td><td>-</td></tr>
<tr><td>Equipment</td><td colspan="2">-</td><td>-</td><td>-</td></tr>
<tr><td></td><td colspan="2">-</td><td>-</td><td></td></tr>
<tr><td colspan="5">Elderly Couple</td></tr>
<tr><td>Human load</td><td colspan="2">Heat. Gen 0.115 kW
Moist. Gen 0.04 kg/h
Number of People 2</td><td></td><td>HUBelderly people week - Mon-Fri
endHUB elderly people - Sat-Sun</td></tr>
<tr><td>Equipment</td><td colspan="2">Heat Load 1.33 kW
Part to Air 0.7 (-)</td><td></td><td>HUBelderly equip week - Mon-Fri
endHUB elderly equip - Sat-Sun</td></tr>
<tr><td>Moisture</td><td colspan="2">Load 0.152 kg/h</td><td></td><td>HUBelderly moist week - Mon-Fri
endHUB elderly moist - Sat-Sun</td></tr>
<tr><td colspan="5">Working Couple</td></tr>
<tr><td>Human load</td><td colspan="2">Heat. Gen 0.14
Moist. Gen 0.06
Number of People - 2</td><td></td><td>HUBwork people week - Mon-Fri
endHUBwork people - Sat-Sun</td></tr>
<tr><td>Equipment</td><td colspan="2">Heat Load 1.167 kW
Part to Air 0.7 (-)</td><td></td><td>HUBwork equip week - Mon-Fri
endHUBwork equip - Sat-Sun</td></tr>
<tr><td>Moisture</td><td colspan="2">Load 0.127 kg/h</td><td></td><td>HUBwork moist week - Mon-Fri
endHUBwork moist - Sat-Sun</td></tr>
<tr><td colspan="5">Infiltration / Lightning / Venting are the same in all scenarios</td></tr>
<tr><td>Infiltration</td><td colspan="2">Basic air change rate 0.1 (/h)
TmpFactor. 0 (/h/K)
TmpPover. 0
WindFactor 0 (s/m/h)</td><td></td><td>Always</td></tr>
<tr><td>Lighting</td><td colspan="2">Task Lightning 0 (kW)
General Lightning 0.2 (kW)
Gen. Lightning Level 250 (lux)
Lightning Type Incandesent
Solar Limit 0.2 (kW)
Exhaust Part 0 (-)</td><td></td><td>Everyday:
7:00 - 8:00
19:00 - 24:00</td></tr>
<tr><td>Venting</td><td colspan="2">Basic air change rate 1.5 (/h)
TmpFactor. 0.1 (/h/K)
TmpPover. 0
WindFactor 0 (s/m/h)
Max AirChange 5 (/h)</td><td>SetPoint 25°C
SetP CO2 0 (ppm)
Factor 1 (-)</td><td>Always</td></tr>
<tr><td colspan="5">Traditional Heating</td></tr>
<tr><td>Heating</td><td colspan="2">MaxPow 1 (kW)
Fixed Part 0.05 (-)
Part to Air 0.6 (-)</td><td>Factor 1.0 (-)
Set Point 20°C/22.0°C
Design Temp –12.0°C
MinPow 0.8 (kW)
Te min: 10.0°C</td><td>Heating-time-Mon-Sun
October - April</td></tr>
<tr><td></td><td>Ventilation unit without moisture recovery Input</td><td>Ventilation unit with moisture recovery Input</td><td></td><td></td></tr>
</table>

Figure 6.10: BSim simulation Systems input part 1

Ventilation Inlet Control	Supply 0.347 m^3/s Pressure Rise 200 Pa Total Eff. 0.6 (-) Part to Air 1.0 (-) Output Return 0.035 m^3/s Pressure Rise 200 Pa Total Eff. 0.6 Part to Air 0.5 Recovery Unit Max Heat Rec 0.92 Min Heat Rec 0 Max Cool Rec 0 Max Moist Rec 0 Heating Coil Max Power 0 kW	Supply 0.347 m^3/s Pressure Rise 100 Pa Total Eff. 0.6 (-) Part to Air 1.0 (-) Output Return 0.035 m^3/s Pressure Rise 100 Pa Total Eff. 0.6 Part to Air 0.5 Recovery Unit Max Heat Rec 0.85 Min Heat Rec 0 Max Cool Rec 0 Max Moist Rec 0.91 Heating Coil Max Power 0 kW	Part of nom. flow 1.0 Point 1 Te1 –12.0 Tinl1 on line 18.0 Point 2 Te2 18.0 Tinl2 on line 18.0 Slope before 0 Slope after 2: 0 Air Hum.: 0	Always
Heat Valve Ventilation				
Heating	MaxPow 1 kW Fixed Part 0 (-) Part to Air 1 (-)		Factor 1.0 Set Point 18°C Design Temp –12.0°C MinPow 0.5 kW Te min: 10.0°C	October - April
	Ventilation unit without moisture recovery	**Ventilation unit with moisture recovery**		
Ventilation Zone Control	Supply 0.56 m^3/s Pressure Rise 200 Pa Total Eff. 0.6 Part to Air 1.0 Output Return 0.056 m^3/s Pressure Rise 200 Pa Total Eff. 0.6 Part to Air 0.5 Recovery Unit Max Heat Rec 0.90 Min Heat Rec 0 Max Cool Rec 0 Max Moist Rec 0 Heating Coil Max Power 1.3 kW	Supply 0.56 m^3/s Pressure Rise 100 Pa Total Eff. 0.6 Part to Air 1.0 Output Return 0.056 m^3/s Pressure Rise 100 Pa Total Eff. 0.6 Part to Air 0.5 Recovery Unit Max Heat Rec 0.85 Min Heat Rec 0 Max Cool Rec 0 Max Moist Rec 0.86 Heating Coil Max Power 1.3 kW	HUBzone winter Part of nom. flow 1.0 Min. Inlet Temp 18°C Max Inlet Temp 35°C Heating Set Pnt 20°C/22°C Cooling Set Pnt 26°C HUBzone summer Part of nom. flow 1.0 Min. Inlet Temp 18°C Max Inlet Temp 18°C Heating Set Pnt 20°C/22°C Cooling Sset Pnt 26°C Air Hum 0	greenHUB winter - Oct-Apr greenHUB summer -

Figure 6.11: BSim simulation Systems input part 2

6.7 LCA Input

In this chapter, the LCAByg input will be discussed. The main focus of this paper is a comparison of two systems Traditional heating and ventilation as one and a Heat Valve Ventilation system in the context of CO^2 emission. Therefore it was decided to omit the building construction in the LCA calculations and include only the materials that are used for the systems.

6.7.1 Traditional system

The materials and components used for the traditional system were found in the LCAByg library, however, some 'amounts' were adjusted according to data available in data sheets for specific elements. The ventilation unit was the only element of the system for which a new product was created in LCAByg with the use of EPD. The data for selected in the project ventilation units was not available so a similar product was found and its EPD certificate was used for input. Used EPD data can be found in Appendix E

6.7.2 Heat valve ventilation system

This system is newly developed and the EPD is not available for the main part of the system which is manifold. Therefore, it was necessary to calculate the use of single elements of the whole unit one by one. It was done based on the list and drawings provided by Lindab and both can be found in Appendix E. The ventilation unit for the HVV system was selected the same as for the traditional system.

The detailed list of materials and elements selected for systems in the LCAByg as well as the used amount is presented in the same Apendix E.

Chapter 7

Heating and Ventilation Systems

7.1 Traditional Heating and Ventilation Systems

7.1.1 Mechanical Balanced Ventilation System

7.1.1.1 Introduction

This chapter explores the implementation of a traditional decentralized mechanical balanced ventilation system with mixing ventilation on selected apartment levels. The core principle behind the design is variable airflow. The design of the ventilation system follows the current Danish Building regulations [17] which describe the rules and parameters that need to be achieved regarding ventilation in residential buildings.

The selected approach for ventilation distribution is the mixing ventilation system. This system is designed to achieve the goal of diluting polluted air with clean supply air at the desired temperature. The room is supplied with air at a high initial mean velocity, which creates established velocity gradients, resulting in increased turbulence intensity. This is done to facilitate effective mixing and ensure a uniform distribution of temperature and pollutants throughout the occupied space. The system is utilizing a variable airflow principle that enables it to dynamically adjust its volume flow and, consequently, its energy consumption when operating at partial loads. The mechanical ventilation system will adopt a balanced ventilation approach, ensuring that the volumes of supply and extraction air are always in a state of balance.

7.1.2 Ductwork and design

The positioning of diffusers and ventilation ducts adheres to the principle of simple design and minimizes duct path lengths to the greatest extent possible. The air handling unit can provide calculated air volume for each apartment and it is placed in the shaft which is easily accessible from the bedroom. The figure below presents how ducts are distributed in the apartment.

The duct network in the apartment is made of circular ducts, which offer the advantage of lower pressure drops compared to rectangular ducts.[16] These ducts are hidden above suspended ceilings, ensuring they do not disrupt the apartment's architectural aesthetics. The ducts are selected to be galvanized steel-sized in accordance with Lindab A/S manufacture. Detailed sizing calculations can be found in Appendix C.

Following the Danish Building Regulations [17], bathroom evacuation requires a minimum airflow of 15 l/s, and kitchen evacuation requires a minimum airflow of 20l/s.

To maintain a balanced ventilation system, the air supply must be carefully designed. As a result, the air supply is intentionally oversized to prevent any pressure imbalances within the apartment. This approach ensures that the supply and extraction air flows remain in equilibrium.

The 7.1 below outlines the required air supply and extraction rates for the apartment:

Room	Area	Supply			Extract	
	[m2]	[l/s/m2]	[l/s]	[m3/h]	[l/s]	[m3/h]
Living room/ kitchen&hallway	43.85	0.6	26.3	94.7		
					20	72
Bedroom	14	0.6	8.4	30.2		
Bathroom	6.55				15	54
Total	65		34.7	124.9	35	126

Table 7.1: Required supply and extraction airflow

7.1.2.1 AHU selection

This section discusses the selection of the decentralized Air Handling Unit. Figure 7.1 shows VEX40T model from manufacturer Exhausto A/S which has been selected. It is a classic decentralized AHU solution for residential applications, particularly in apartment buildings. The VEX40T offers a compact and efficient solution that fulfills selected apartment requirements. Due to its compact design, the unit can be easily in small spaces. AHU is installed in the shaft which is accessible from the bedroom. The AHU incorporates a built-in bypass function to enhance energy efficiency and heat recovery. Its maximum output is 330 m3/h at 200 Pa and its temperature efficiency of 92% at 126 m3/h.

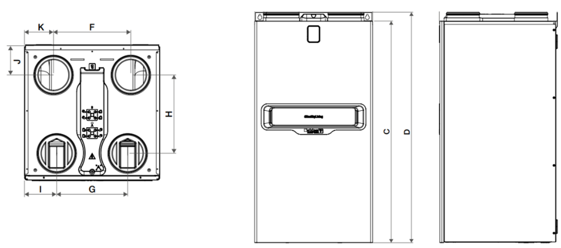


Figure 7.1: Exhausto VEX40T Air Handling Unit

Additionally, it was decided to investigate if the use of a ventilation unit that has the possibility of moisture recovery, can help with the maintenance of a satisfying level of relative humidity in the apartment. For this purpose, the ECO360R ventilation unit from

GENVEX was chosen. This system is characterized by lower heat recovery, up to 86% however thanks to the special rotary heat exchanger that recovers moisture from the extracted air. The maximum air volume for the system is up to 410m3/h at 100Pa. For the needs of the traditional system in this project, the temperature efficiency is 85%, and the moisture recovery of 91%. Graphs that were used to select the proper temperature efficiency for both units and moisture recovery for the second unit can be found in Appendix C

7.1.3 Traditional Heating System

In this chapter, the traditional heating systems will be elaborated, and their design process will be presented. Before the design of the system, some decisions about the system had to be made. As it was known from the documentation the water-based heating system will be used in the project. The building will be connected to district heating with as low a supply temperature as 40°C. The common heating system used in apartment buildings in Denmark is radiators therefore this type will also be used for this project. First, it was decided that the heat distribution would be distributed by connecting the radiators with the two-pipe system.

This is more energy-efficient and ensures even distribution of heat to each of the radiators. The pipes will be mounted in the floor structure which will help to minimize the use of the material by avoiding the need for leading extra pipes from the top of the room. Moreover, this way of the placement of the pipes will not disturb the aesthetic aspect of the apartment. Another important decision was the pipe material. It was decided to use the copper piping.

Designing heating systems has to start with the calculation of heat demand for each space in the apartment. To get that, first, the transmission loss had to be estimated.The calculated heat demand for each room is presented in Table 7.2 below.

	Heating demand		
	Trans. heat loss [W]	Vent. heat loss [W]	Total heat loss [W]
Entrance/ Kitchen / Living area	608.6144	63.67	672.2856524
Bathroom	33.408	0.00	33.408
Bedroom	231.6672	18.45	250.120005

Table 7.2: Heat demand for radiators in rooms

7.1.3.1 Radiators and pipe work

According to the presented above heat losses, the number of radiators for each of the rooms and their sizes were selected. The detailed calculations can be found in Appendix C. In the table 7.3, below, the final choice of radiators is introduced. All the radiators were selected from the PURMO catalog. For rooms the model COMPACT was selected and for the toilet model FLORES.

		Living room/kitchen	Bedrom	Bathroom
Heating demand ()	[W]	672	250	33
Amount of radiators	-	2	1	1
Heating demand per radiator ()	[W]	336	250	33
Model Name	-	C33 450 1400	C22 450 1400	FLO0505
Height	[mm]	450	450	547
Width	[mm]	1400	1400	500
Actual heating output	[W]	352	255	34

Table 7.3: Selection of radiators

When it comes to pipework for the heating system based on MagiCAD calculation the Ø15mm pipes were used in this project. The results of MagiCAD calculation can be found in Appendix C

Chapter 8

Heat Valve System

8.1 Theory and Principle of Heat Valve Ventilation System

In this chapter, we delve into the design of heat valve ventilation systems. The chapter describes the working principles of the system and the differences between typical mechanical ventilation systems.

The HVV system represents a modern, integrated approach to delivering heat to individual zones through the air. The system combines ventilation and heating solutions into a single unit, the solution not only simplifies the overall system design but also enhances its performance and energy efficiency.

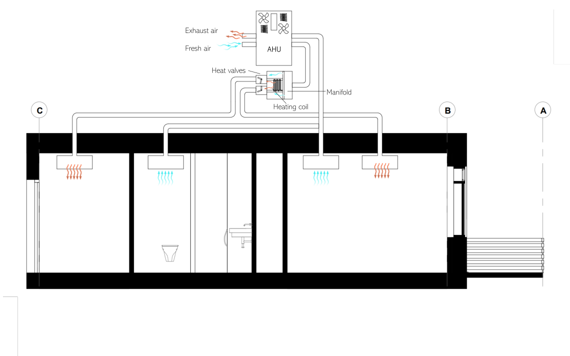


Figure 8.1: Schematic design of HVV system

Figure 8.1 presents a simplified diagram of the heat ventilation system. The HVV system includes the following key components: a decentralized Air Handling Unit with filters, supply and extract ductwork, and a manifold with a heating coil and heat valve. Two last components play a pivotal role in making sure the fresh ventilated air is heated for the specific needs of each zone. The system can be designed to operate in both Variable Air Volume (VAV) and Constant Air Volume (CAV) and it has been tested using CAV [15] [8] [12] and VAV. [14]

The air supply process begins with drawing fresh air from the outside into the AHU where it is warmed up by heat recovery and then passed to the manifold that distributes airflow rate into separate ducts and then to the rooms which is its main purpose. The manifold consists of a heating coil that maintains the heating in the HVV system by heating up the air to the temperature required in the individual rooms. Circular ducts used in the system are similar to traditional ventilation systems.

As stated in Danish Building regulations, [17] in residential buildings there must at all times be an outside air supply of at least 0.30 l/s per m² heated floor area. Extraction from bathrooms and toilets in homes must be able to be increased to at least 15 l/s. In toilets without a bath and in utility rooms, it must be possible to extract at least 10 l/s. HVV system provides adequate airflow rates to deliver fresh air to spaces in the apartment and meet the building regulations.

8.2 Manifold design

The core component of HVV is the manifold, which is an air distribution element that manages the flow of heated air. A series of smaller ducts are connected to the manifold, ensuring control over airflow distribution to individual rooms within the apartment. The manifold consists of three layers that are visible on the cross-section of the manifold in figure 8.2. Two parts which are situated on top and bottom of the manifold are isolated to prevent heat transfer between the main central part where the heat coil is installed. perforated plate This design allows for the flexible passage of air, either bypassing or passing through a heating coil. The airflow pattern through the manifold is controlled by the positioning of heat valves.

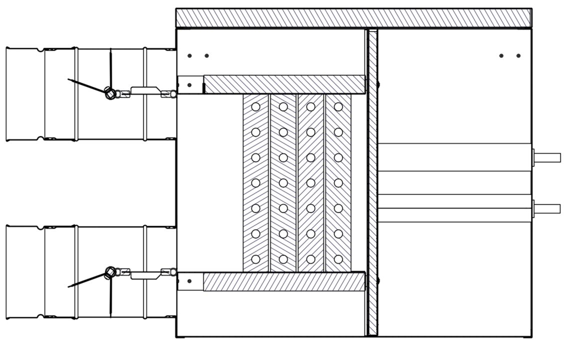


Figure 8.2: Manifold cross section

Figure 8.3 shows the heat valves which, consist of two blades that can be regulated. The angle of these blades determines the proportion of air that either passes through or bypasses the heating coil. Each valve has a regulation mechanism that allows for exact control, ranging from 0 to 100%. When set to 0%, the total airflow bypasses the heating coil. On the other hand, at 100% the total amount of air passes through the heating coil, ensuring maximum heating output. When blades are positioned between the range 0 – 100% the air is split into two, partly bypassing the heating coil, and then is being mixed. The positioning of each heat valve, and thereby the supply air temperature in each duct, is controlled by the actuator. The actuator receives a signal from the room controller which monitors the present air temperature and compares the measurement to defined temperature set points. This way the temperature of the conditioned air can be easily controlled.

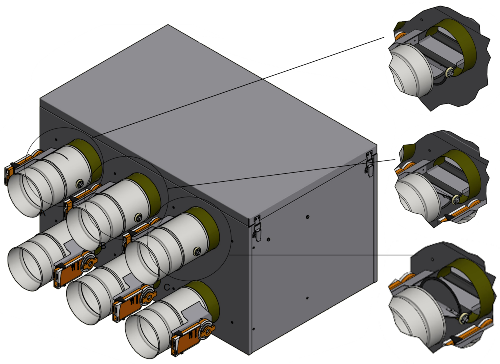


Figure 8.3: Manifold design

8.3 HVV system calculation

In this section, the airflow required for each room to maintain the heating of the space will be calculated. For this purpose, the guideline from *Polak, Joanna* [12] was used.

The system must be able to compensate for the transmission, infiltration, and ventilation losses for each of the rooms [12]. Detailed heat loss calculations are presented in the Appendix A for this project were already calculated.

First, the heating power delivered to the rooms was calculated. As it is known from the guideline, similar to the traditional ventilation system the air is supplied only in the habitable areas which in this project are the bedroom and living room with kitchen. It means the bathroom as it is directly connected to the living room area was included in the heating power requirement of this space. In this case, the final heat demands for two spaces is presented in Table 8.1

	Trans. heat loss (t)	Vent. heat loss (v)	Total heat loss
	[W]	[W]	[W]
Living room/bathroom	642.0	63.7	705.7
Bedroom	231.7	18.5	250.1

Table 8.1: Heat demand for heated spaces

The supply air capacity was calculated with use of the following formula:

$$P_i = q_{v,i} \times \rho_{a,i} \times c_{p,a} \times (T_{supply_{air},i} - T_{room,i})$$

where P_i (W) is the heating power delivered to the room. $q_{v,i}$ (m^3/s) is the airflow rate supplied to the room and this is the value that will be calculated. $p_{a,i}$ (kg/m^3) is the supplied air density, which in this case will be 1.145 kg/m3 and the $c_{p, a}$ is 1007 J/(kgK). These last two values were found for the supply air temperature $T_{supplyair,i}$ (K) which is 35°C = 308.15K. This is the maximum possible temperature for the airflow according to DS469 [19]. The last needed number is the air temperature in the room, for needs of this calculation, is 20°C which is the design indoor temperature.

The final results of the required airflow for the Heat Valve Ventilation system are presented in Table 8.2 below. The detailed calculations can be found in the appendix C

	Airflow rate supplied		Heat demand	Heat power delivered
	[m3/h]	[m3/s]	[W]	[W]
Living room	150	0.042	705.7	720.6
Bedroom	53	0.015	250.1	254.6
Total	203	0.056	955.8	975.3

Table 8.2: Heat valve ventilation system airflow requirement

Moreover, the Heat Coil was dimensioned with use of AIAcalc software and the final results can be found also in Appendix C

Chapter 9

Strategies Simulations

The software tool BSim was used to conduct dynamic simulations of all scenarios and explore the parameters of the individual apartment representing the whole building. For the simulations, the weather data for the period from January to December 2022 was used. The heating was operating from October to March. [20] The data was analyzed on a monthly basis to capture seasonal variations and provide a comprehensive understanding of the system's performance.

This chapter is divided into 3 sections according to three scenarios. For all scenarios, heat demand was calculated based on data presented in Chapter 7 without heat gains from occupants or equipment. The total heat demand was determined to be 672.3W for the living room, and kitchen with entrance, 250.5.00W for the bedroom, and 33.4W for the bathroom. In the first scenario, the apartment was simulated with no additional heat gains. It represents a baseline condition where no internal heat sources are contributing to the indoor environment. The second scenario introduced heat gains from an elderly couple residing in the apartment. This occupancy profile produces higher metabolic heat compared to the last scenario since elderly people tend to spend more time at home. The third scenario experiences heat gains generated by a working couple. For each of those scenarios, simulations were conducted for temperature set points of 20°C and 22°C. According, to DS418 [3] 20°C is a design indoor temperature. Additionally, it was important to keep the temperature within the comfort range and it was found that 22°C is a comfortable operative temperature while 20°C is a minimally comfortable operative temperature.

For each of the three scenarios, simulations were conducted with two variants of ventilation units to assess the impact of moisture recovery on indoor air quality and moisture levels within the apartment. The first variant was a ventilation unit without moisture recovery that allowed for efficient heat recovery at 90-92%. The other one was with lower heat recovery at 85% however also with possibility of moisture recovery with efficiency up to 92%.

The table 9.1 illustrates various scenarios, variants, and the structure outlined in the following chapter.

	Variant	Set point	Heat recovery	Moisture recovery
		[C°]	[-]	[-]
Traditional	without moisture recovery	20 22	0.92	X
	with moisture recovery	20 22	0.85	0.91
HVV	without moisture recovery	20 22	0.9	X
	with moisture recovery	20 22	0.85	0.86

Table 9.1: Overview of simulated variants for both sytems

9.1 Simulation for design temperatures without occupants or heat gains

The first scenario aimed to assess the energy consumption, efficiency and thermal comfort of both systems in cases where no people or equipment are present in the apartment. This setups, allowed for a focused evaluation of the core functionalities of the heating and ventilation systems. The primary focus of those scenarios is to evaluate and compare the energy performance, indoor temperatures and moisture levels in the rooms associated with each strategy. Those parameters are crucial for understanding the overall energy effectiveness and indoor environmental quality.

9.1.1 Energy consumption

In this section, the energy consumption of simulated systems is presented and analyzed. Tables 9.2 and 9.3 shows the energy consumption for traditional systems and HVV system respectively. The tables illustrate energy used for heating and the fan power. The data is present for four different variants including different temperature set points and variants of ventilation units with and without moisture recovery.

Set Point Temperature [°C]	20°C	22°C	20°C	22°C
Moisture Recovery			**X**	X
qHeating [kWh]	2571.43	3459.27	2694.75	3462.76
Fan Power [kWh]	203.52	203.52	101.76	101.76
Total [kWh]	2774.95	3662.79	2796.51	3564.52

Table 9.2: Energy consumption of traditional system with no heat loads

Set Point Temperature [°C]	20°C	22°C	20°C	22°C
Moisture Recovery			X	X
qHtCoil [kWh]	2615.49	3086.88	3006.47	3523.15
Fan Power [kWh]	327.04	327.04	163.52	163.52
Total [kWh]	2942.53	3413.92	3169.99	3686.67

Table 9.3: Energy consumption of HVV system with no heat loads

In this scenario where the heat gains are not included, for both of the systems, it is visible that when the ventilation unit with moisture recovery is used traditional system has better energy performance than the Heat Valve Ventilation system. When it comes to the ventilation unit without moisture recovery and with higher heat recovery the situation is different. For the lower temperature set point traditional system also has lower energy consumption than the HVV, however for the higher set point of 22°C the HVV system performs better.

9.1.2 Thermal comfort

The next important aspect that has to be evaluated is thermal comfort. As mentioned earlier, there were two temperature set points used for the systems which means that during the heating season temperature always oscillates either around 20°C or 22°C depending on the set point.

The figure9.1 presents the mean temperature and the number of hours below 20°C in the apartment over the year for the Traditional system. The presented data is for a temperature set point of 20°C and 22°C and variants with and without moisture recovery.

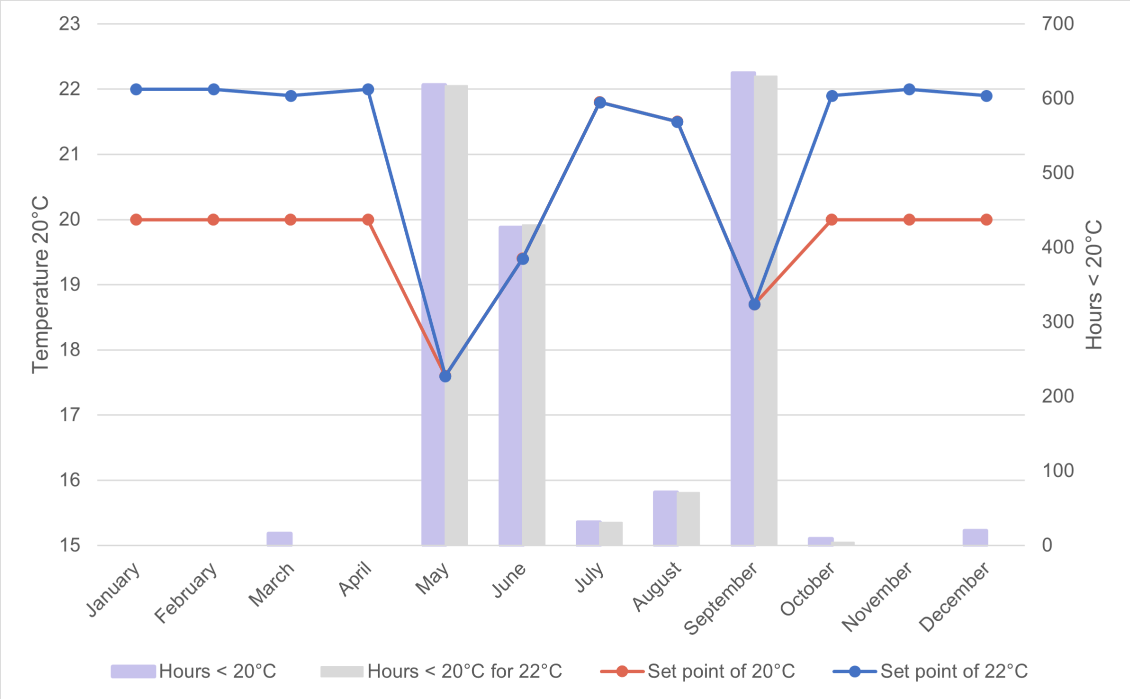


Figure 9.1: Mean temperature and number of hours below 20°C throughout the year for Traditional system baseline

From January to April, the average temperature is at the set point range registering a minimal amount of hours below 20°C in March and only for the set point of 20°C. This temperature drop however is not sufficient and lasts just for a total number of 16 hours. In May, it can be seen that there is a drop to 17.6°C supported by slightly over 600 hours below 20°C. June sees a temperature rise, however, there are almost 400 hours below 20°C registered. In July and August the temperature rises and remains above 21°C, however respectively, around 30 and 70 hours below 20°C are recorded. It can be seen that in September temperatures drop and there is a rise of hours to over 600 hours.

The second evaluated variant of mean temperatures and amounts of hours below 20°C is for a set point of 22°C. From January to April, the average temperature is at 22°C. Similar to the previous case of 20°C, in the heating season the temperature oscillates around the set temperature of 22°C. Because of the higher set point, there are no hours below 20°C recorded for the heating season. For the cooling system, the mean temperatures and recorded hours below 20°C are similar to the previous set point.

The next figure 9.2presents the same set of data for the HVV system. As it is seen, similar to traditional systems, during the heating season, the temperature oscillates around the given temperature set points.

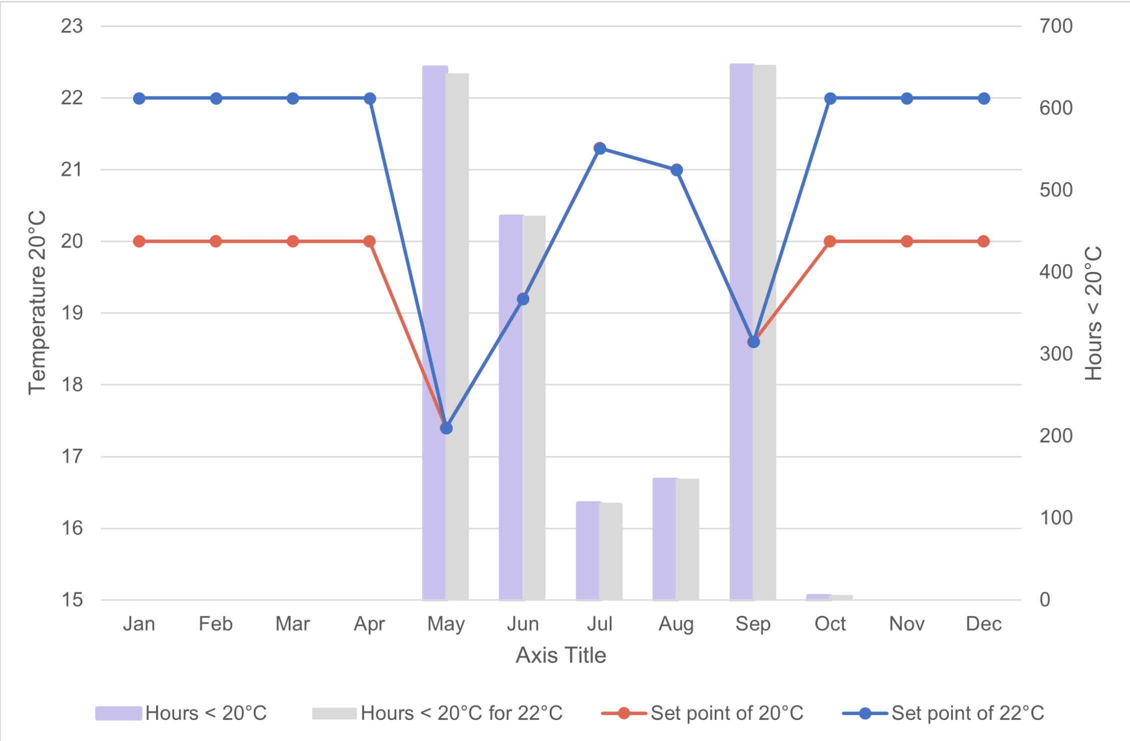


Figure 9.2: Mean temperature and number of hours below 20°C throughout the year for HVV system baseline

Outside of the heating system in May and September, the temperature experiences a drop to 17.4°C and 18.6°C, respectively. In terms of the number of hours below 20°C, the highest numbers occur also in May and September where each month totals almost 650 hours. Also in June, July, and August the hours below 20°C were recorded but with lower numbers of 430, 130, and 170 respectively. In August there is a peak in temperature to over 21°C.

9.1.3 Moisture levels

In this section, the relative humidity in the apartment will be evaluated. As in previous sections, there were 4 simulations conducted for each of the systems, two for the system with moisture recovery and two without moisture recovery.

Figure 9.3 and Figure 9.4 present relative moisture in the apartments for set Traditional and HVV systems respectively.

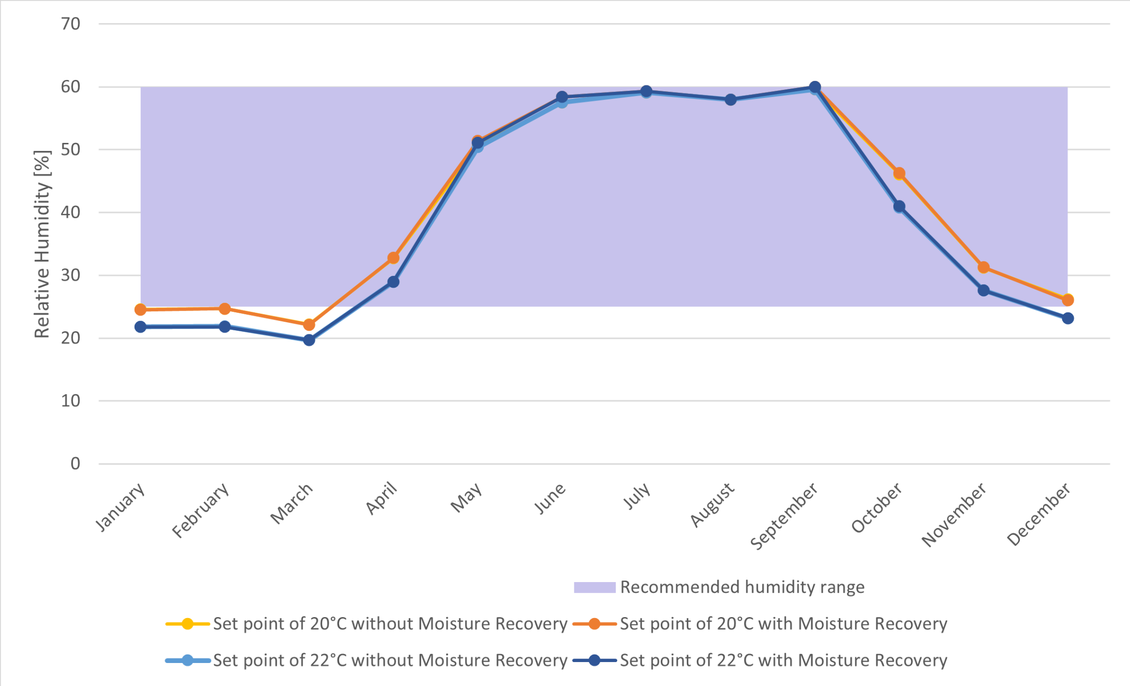


Figure 9.3: Average relative humidity in traditional system baseline

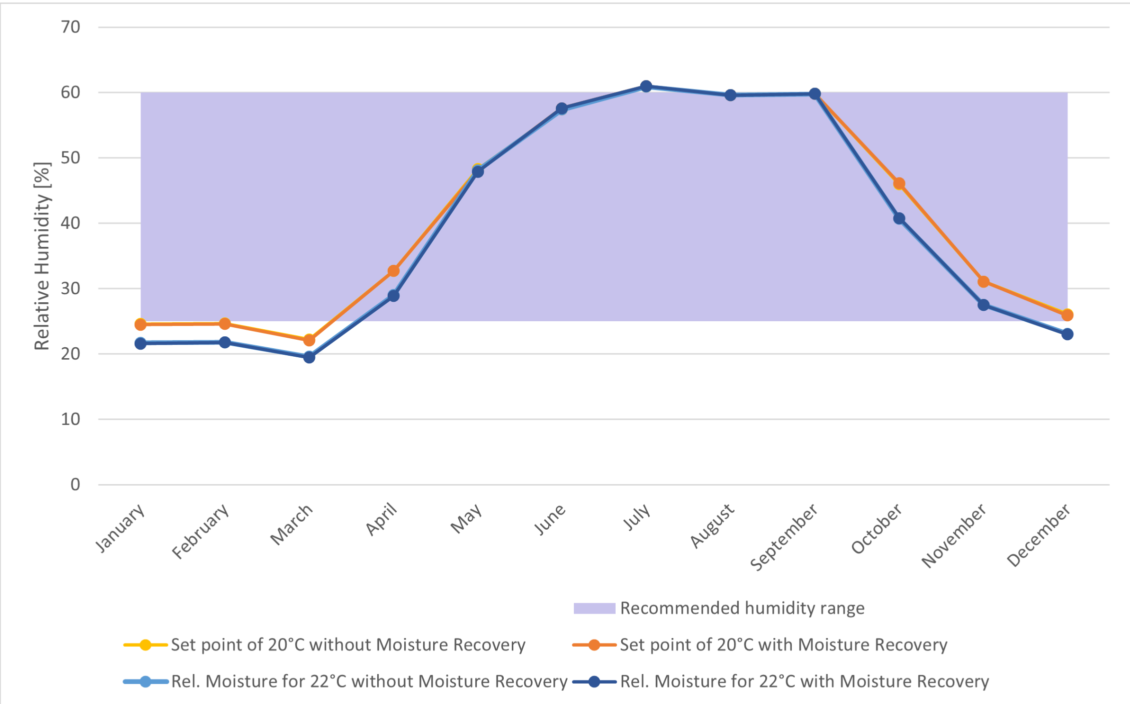


Figure 9.4: Average relative humidity in HVV system baseline

As seen in both figures, the general tendency is that the warmer months are characterized by higher humidity, while the colder months tend to be drier. It also can be noticed that for higher set points the humidity level in the heating season remains lower than for the 20°C set point. From January to March, the apartment exhibits a relatively low humidity that remains below the recommended range and in the most critical month, March, drops as low as 20%. As April arrives, there is a notable pick in humidity in both cases, May witnesses a substantial rise in relative moisture, indicative of a transition to higher humidity levels commonly associated with the warmer spring season. The summer months exhibit the highest levels of relative moisture reaching 60% in both scenarios, likely influenced by warmer temperatures and increased outdoor humidity. As summer transitions to fall, October marks a shift with a decrease in relative humidity, suggesting a decline in humidity as autumn progresses. November experiences a continued reduction in moisture levels and by December, the trend continues. For both of the systems the humidity level in the heating season, from January to March and in December stays below the recommended humidity range for the apartments. The lowest drop is noticeable in March. As visible in the figure above, which represents the moisture level through the month, the Humidity stays below 25% for a significant period. It is also important to mark that the low moisture level is directly connected to the outdoor temperature below 0°C. and what requires the higher heat output in the case of traditional system and higher inlet temperature in the HVV systems. It is also visible that with the lower temperature set point (20°C) the moisture is higher than in case of set point of 22°C. As it is also seen in the figures in both systems, when there is no moisture gains the moisture recovery does not influence the moisture level in any significant way.

9.1.4 CO^2 level

For this scenario, the CO^2 level remains at 350ppm because there are no CO^2 sources implemented into the simulation.

9.2 Simulation with heat and moisture gains

In the next two sections, the scenarios which consist of added heat gains from people and equipment as well as the moisture loads will be presented. First, the scenario will be simulated for the apartment where the elderly couple lives and the second for the working couple. The gains vary depending on the occupant's daily scheduled and behaviors. The detailed load calculations are presented and available in Appendix B.

9.2.1 Elderly couple

In this section simulation results for the apartment where the elderly couple is living are presented. Similarly to the previous part of the chapter, there were four different simulation runs for each of the systems. This part also evaluates energy consumption, thermal comfort, CO2, and moisture levels.

9.2.1.1 Energy Use

Table 9.4 presents energy consumption under different set point temperatures, with a focus on heating energy, fan power, and overall annual energy consumption. In table 9.5 the same set of energy consumption results for the HVV system can be found.

Set Point Temperature [°C]	20°C	22°C	20°C	22°C
Moisture Recovery [-]			X	X
qHeating [kWh]	859.9	1549.6	954.1	1552.1
Fan Power [kWh]	203.5	203.5	101.8	101.8
Total [kWh]	1063.4	1753.1	1055.9	1653.9

Table 9.4: Energy consumption of traditional system with Elderly Couple

In the traditional system, the total energy consumption of the system is for the 20°C set point for both variants with and without moisture recovery is comparable with slightly better results for the simulation with moisture recovery. For 22°C the difference is bigger, however, the system with moisture recovery still has a lower total energy consumption than one without.

Set Point Temperature [°C]	20°C	22°C	20°C	22°C
Moisture Recovery [-]			X	X
HtCoil [kWh]	897.6	1339.4	1136.2	1645.8
Fan Power [kWh]	327.1	327.1	163.5	163.5
Total [kWh]	1224.7	1666.5	1299.7	1809.3

Table 9.5: Energy consumption of HVV system with Elderly Couple

For the HVV system, unlike the traditional system, for both temperature set points, the system with a ventilation unit without moisture recovery has a better energy performance than the one with. Similar to the traditional system, the difference in energy consumption for 20°C set point is smaller than in the case of 22°C

9.2.1.2 Thermal Comfort

In this section, the results for thermal comfort with the elderly couple living in the apartment will be presented. Figure 9.5 presents the mean monthly temperature throughout the year and the number of hours below 20°C for two temperature set points, 20°C and 22°C for the traditional system. Figure 9.6 shows the same set of results for the HVV system.

As seen in the figure 9.5, below, the monthly average temperature for most of the heating season follows the given temperature set point. In April and October, however, the recorded average temperature is higher at around 1.5°C when the set point is 20°C and around 0.5°C when the set point is 22°C. There are no recorded hours below 20°C for the system.

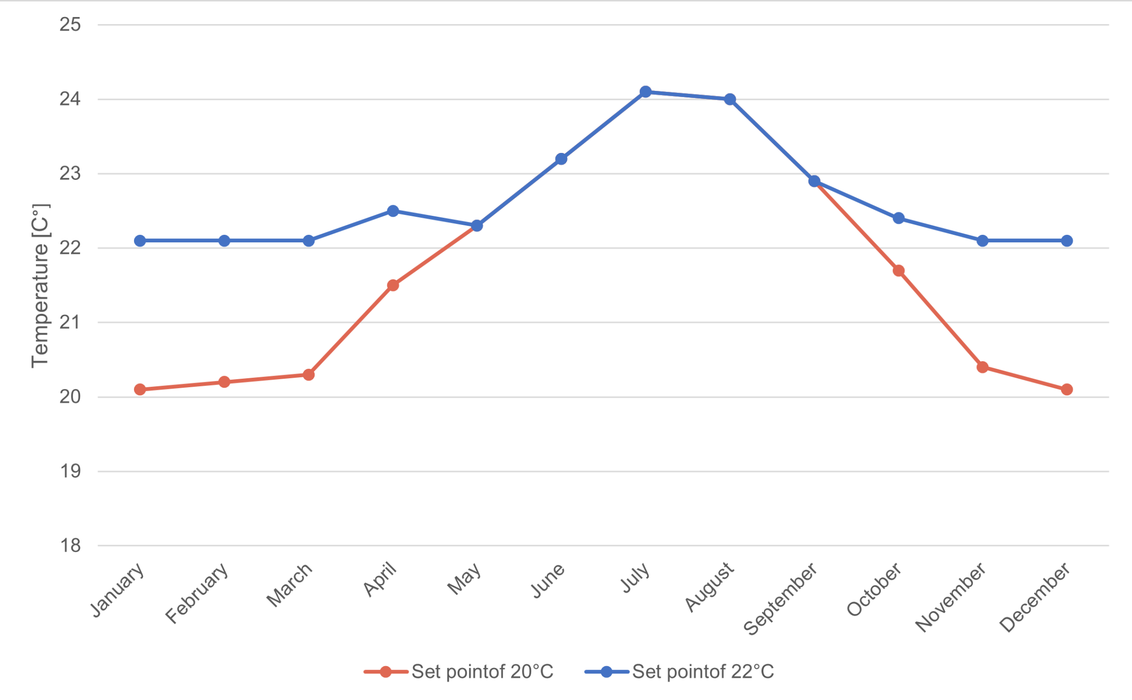


Figure 9.5: Mean temperature and number of hours below 20°C throughout the year for Traditional system with ventilation unit without moisture recovery, for elderly couple

The next figure presents the same set of results as the previous one. Similar to the traditional system the mean temperature from January to March and November to December follow the set point and in April and October the recorded mean temperature is slightly higher than the set point. However, in this case, the difference is smaller, and for a set point of 20°C it is around 0.7°C higher, and for 22°C around 0.2°C. Also unlike the traditional system, for the HVV system there are recorded hours below 20°C, for May it is 26 hours, for June 9, and for September 7. It is also visible that compared to the traditional system the mean temperature outside of the heating system is lower for the HVV system.

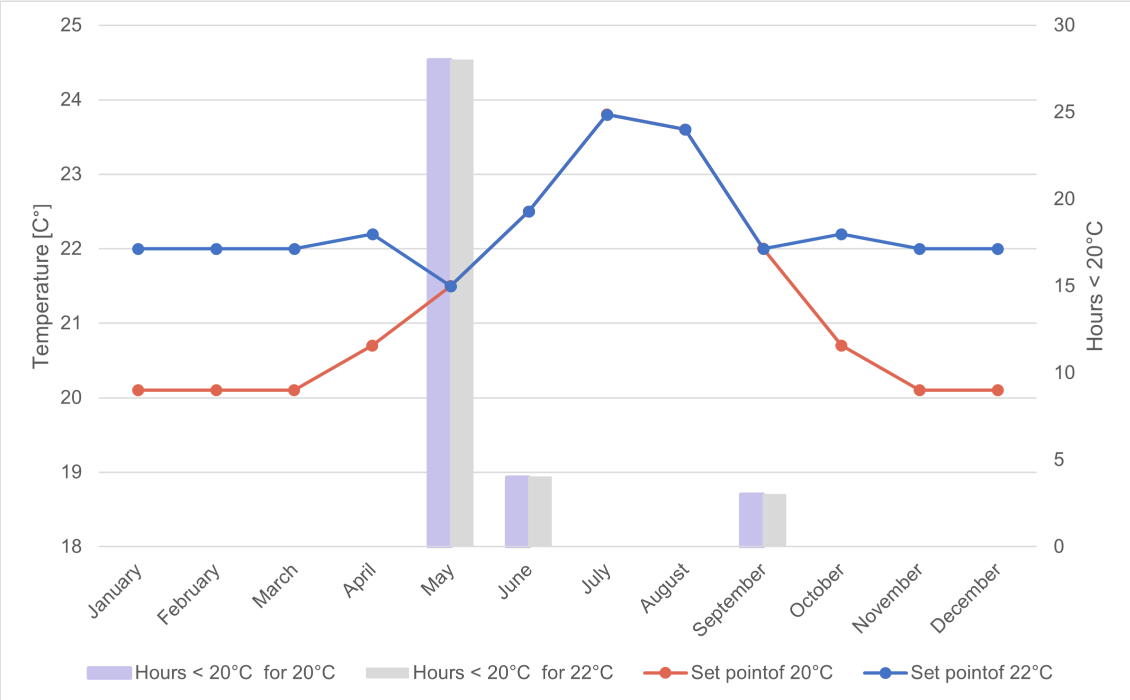


Figure 9.6: Mean temperature and number of hours below 20°C throughout the year for HVV system with ventilation unit without moisture recovery, for elderly couple

Presented temperatures and hours below 20°C are the results of simulations for the ventilation unit without the moisture recovery. The results of the simulation where the ventilation unit has moisture recovery were not presented because it does not influence any of the mentioned aspects in a significant way and are almost the same. The detailed results can be found in Appendix D.

9.2.1.3 Moisture levels

Moisture is the next aspect that was simulated for all scenarios. Figure 9.9 presents moisture levels for cases with and without moisture recovery for set points 20°C (orange shades) and 22°C (blue shades), respectively, throughout the year for the traditional system. In all cases it is visible that the summer months of July and August show elevated humidity levels, reaching almost 55%. in both cases. During winter months, the relative moisture levels drop, with March recording the lowest numbers. However, for the temperature set point of 20°C the average moisture level still stays within the recommended moisture level while for higher temperatures from January to March stays slightly below that range. Both figures illustrate that during the summer months, there is no significant difference in relative humidity. Moreover, it can be seen that the presence of moisture recovery effectively increases the moisture levels during colder months.

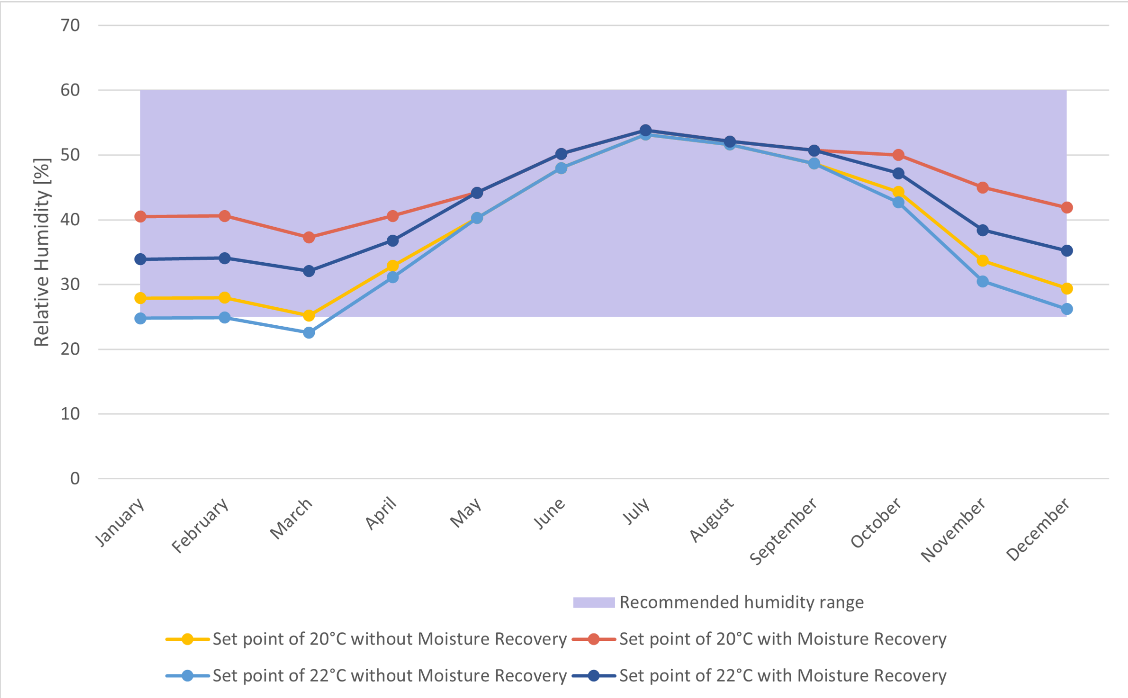


Figure 9.7: Relative humidity for a traditional system for elderly couple

Figure 9.8, below, shows the influence of the presence of moisture recovery in March for a set point of 22°C. This was the month when the simulated average relative humidity was the lowest for the traditional system. It can be seen that the use of a ventilation unit with moisture recovery significantly increases the level of moisture in the apartment and the periods when the humidity level is below 25% are reduced to the minimum.

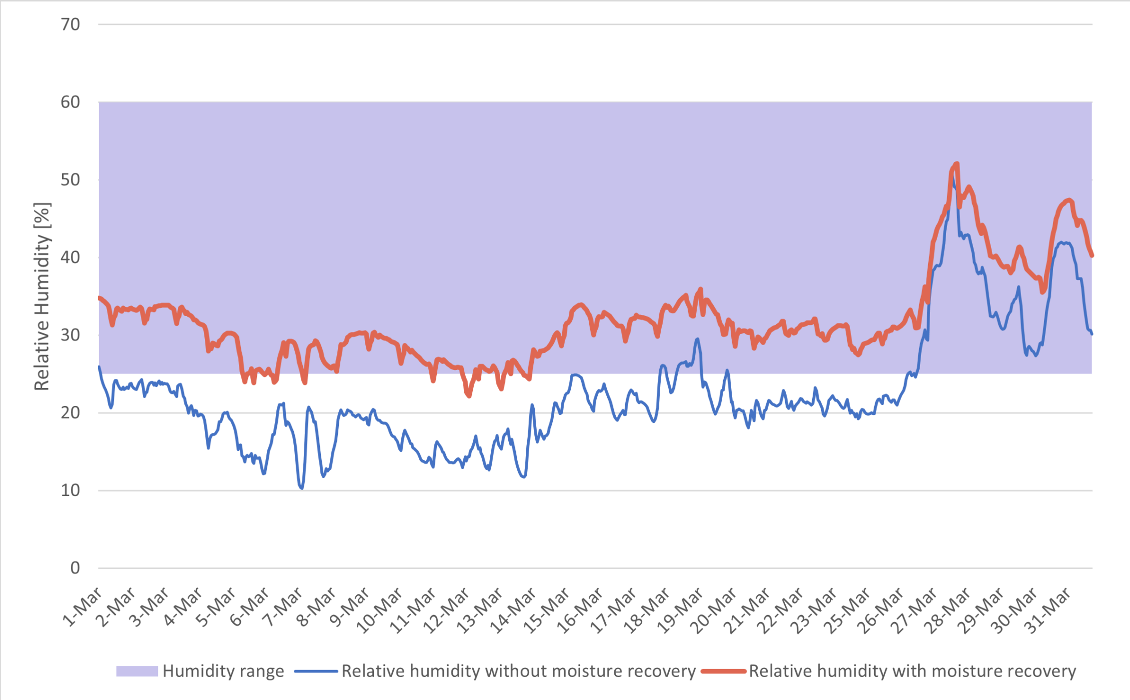


Figure 9.8: Relative humidity in March for a traditional system with a set point of 22°C

The next figure 9.9 also presents relative humidity for the HVV system, for both set points and with and without the moisture recovery. As it is seen the pattern throughout the year remains the same as for the traditional system, with higher moisture from April to November and lower from January to March and in December. Moreover, in comparison to the traditional system, it is noticeable that for HVV, the relative humidity is lower for the same temperature set point and the recovery of the moisture is also smaller.

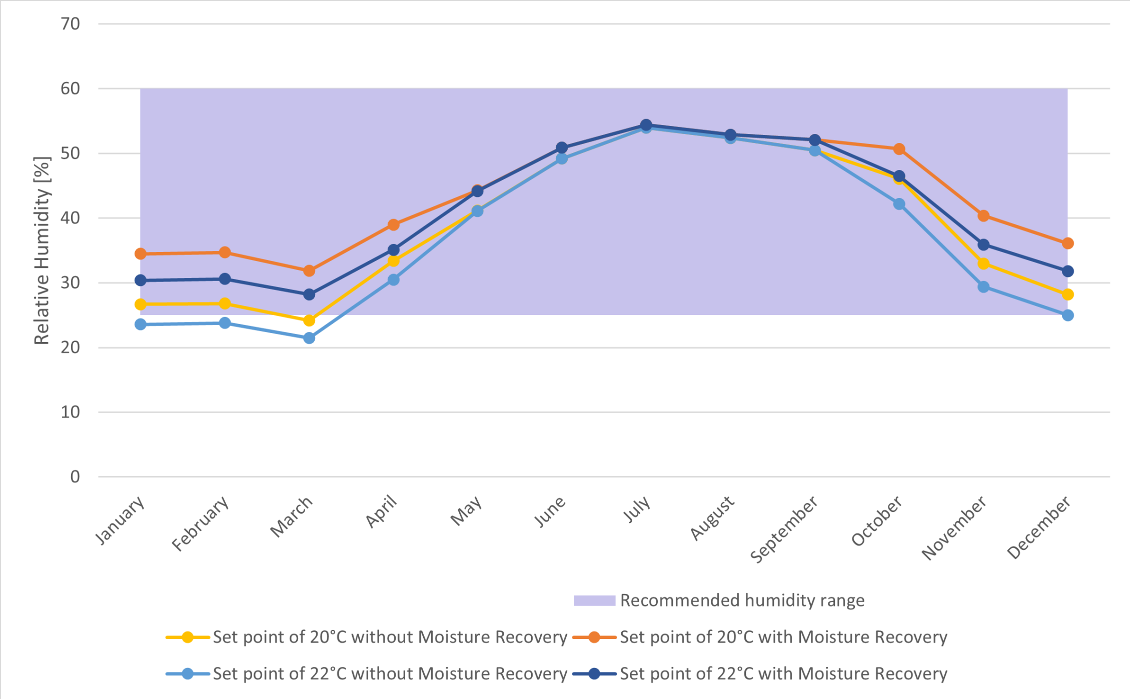


Figure 9.9: Relative humidity for HVV system for elderly couple

The last figure 9.10 presents the relative humidity level with and without moisture recovery for the temperature set point of 22°C. It is seen that even if the ventilation unit has recovered the moisture the humidity level remains below the comfortable range for longer periods than in a traditional system.

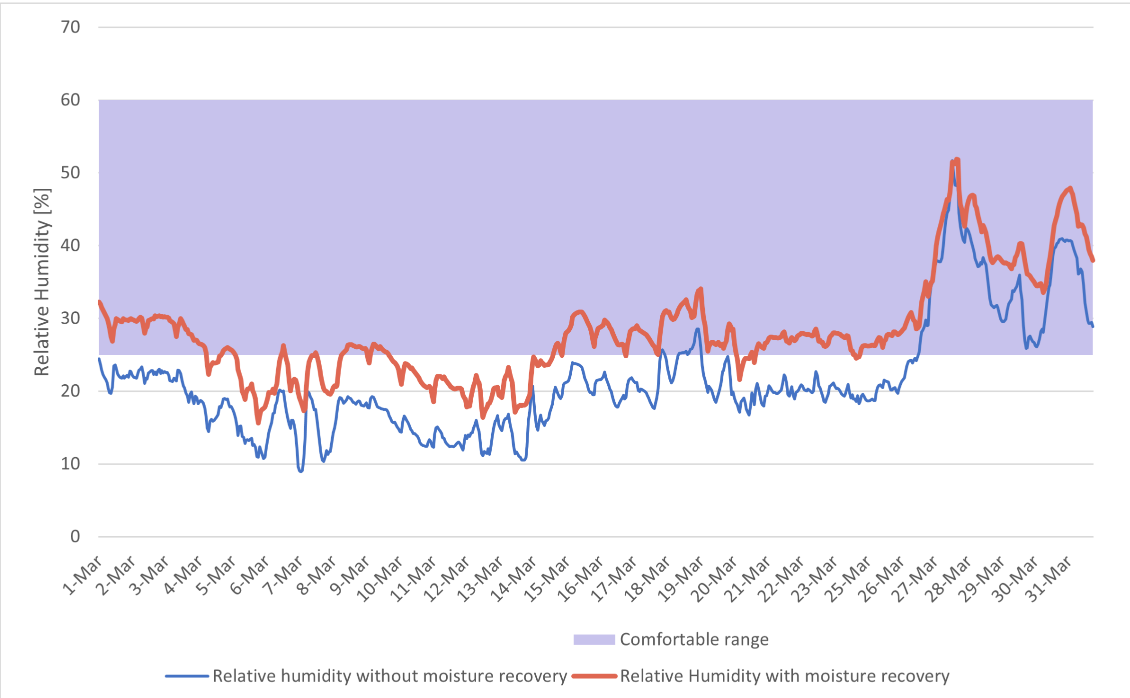


Figure 9.10: Relative humidity in March for an HVV system with a set point of 22°C

9.2.2 CO^2 level

For this scenario, the average monthly CO^2 level remains between 430 and 477ppm for traditional systems, and for HVV systems it is between 415 and 455ppm throughout the year,

9.2.3 Simulation for working couple

The following section involves a scenario in which the occupants are a working couple. Human end equipment heat gains as well as moisture loads are incorporated into the simulation. Similar to previous sections, there are variants with an air handling unit equipped with moisture recovery and without, and simulations are conducted for two set point temperatures.

9.2.3.1 Energy Use

Table 9.6 displays energy consumption variations across different set point temperatures, emphasizing heating energy, fan power, and overall annual energy consumption from the traditional system when the apartment is occupied by a working couple. As it it can be seen for the temperature set point of 20°C the difference in total consumption is minimal and the system without moisture recovery performs slightly better. For 22°C, it is the opposite, and better results are recorded for the system with moisture recovery.

Set Point Temperature [°C]	20°C	22°C	20°C	22°C
Moisture Recovery [-]			X	X
qHeating [kWh]	1099.9	1850.0	1223.2	1865.1
Fan Power [kWh]	203.5	203.5	101.8	101.8
Total [kWh]	1303.4	2053.5	1324.9	1966.9

Table 9.6: Energy consumption of traditional system for working couple

Table 9.7 presents the same results but for the HVV system. In this system, for both temperatures, the system without the moisture recovery has better energy performance.

Set Point Temperature [°C]	20°C	22°C	20°C	22°C
Moisture Recovery [-]			X	X
qHtCoil [kWh]	1209.0	1663.1	1488.0	2006.5
Fan Power [kWh]	327.0	327.0	163.5	163.5
Total [kWh]	1537.0	1990.2	1561.5	2170.0

Table 9.7: Energy consumption of HVV system for working couple

9.2.3.2 Thermal Comfort

Regarding thermal comfort, the figure 9.11 below illustrates the mean temperature in the apartment for two set points, 20°C and 22°C for the Traditional system without moisture recovery. It is visible that for a set point of 20°C it constantly stays slightly above it with a margin of +0.1°C to +0.3°C. For higher set points for most of the months, the mean temperature stays at 22°C with April and October rising 0.3°C above. From May to September the average temperature for both set points remains the same. A peak in temperature, reaching 24.4°C, occurs in July. When it comes to hours when the temperature drops below 20°C, the problem occurs in May and June as well as September with 57 hours, 19 hours, and 14 hours respectively.

There was no significant difference in mean temperature when the ventilation unit with moisture recovery was used or not. For the hours below 20°C in May it was registered 2 more hours which gives a total of 59 hours and in June 3 more hours which gives a total of 22°C. In September, the same as before temperature below 20°C was present for 14 hours.

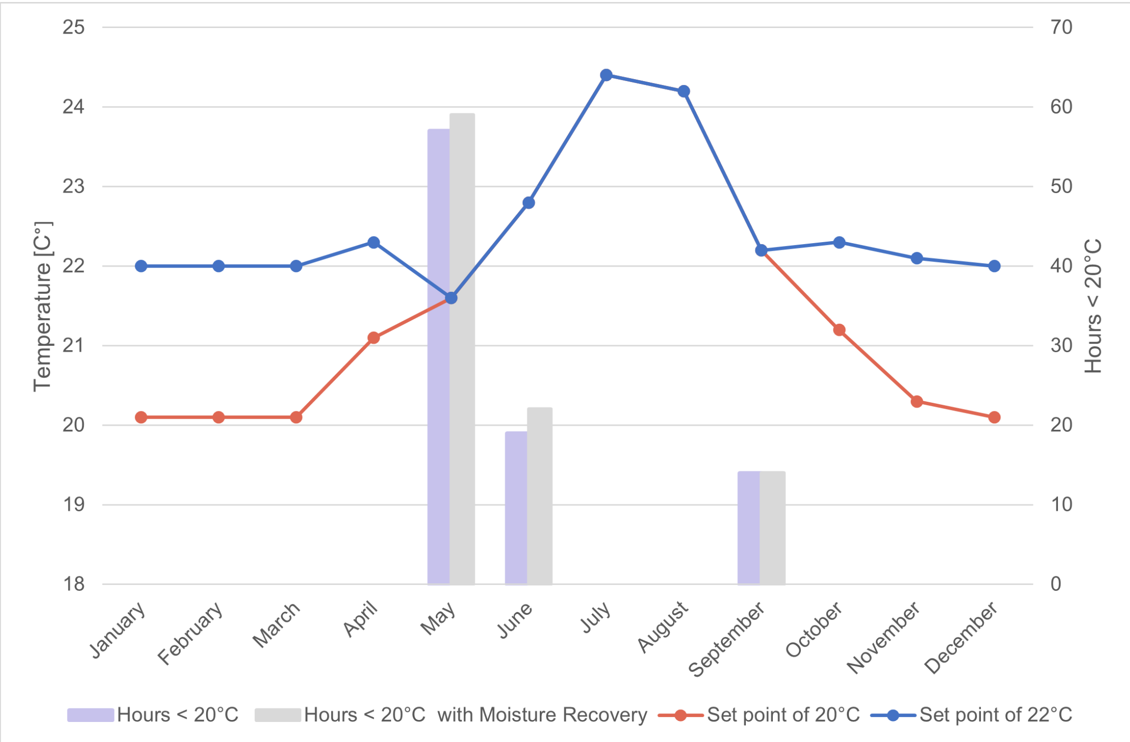


Figure 9.11: Mean temperature and number of hours below 20°C throughout the year for Traditional system with ventilation unit without moisture recovery for working couple

Next figure 9.12, presents the mean monthly temperature for the HVV system. The temperature consistently remains around the given set points of 22°C during the heating season. A similar pattern can be seen for the set point of 20°C except in April and September when the average temperature is slightly higher and it is 20.4°C. From May to September the average temperature for both set points stays the same. A peak in temperature, reaching 23.7°C, occurs in July. When it comes to hours when the temperature drops below 20°C, the problem occurs in May and June with 215 hours and 54 hours respectively for systems without moisture recovery. There was no significant difference in mean temperature when the ventilation unit with moisture recovery was used or not. However, when it comes to the hours below 20°C for May and June this amount is slightly higher with 225 hours and 55 hours respectively. Additionally, the temperature drops below this temperature also in September for a total of 35 hours.

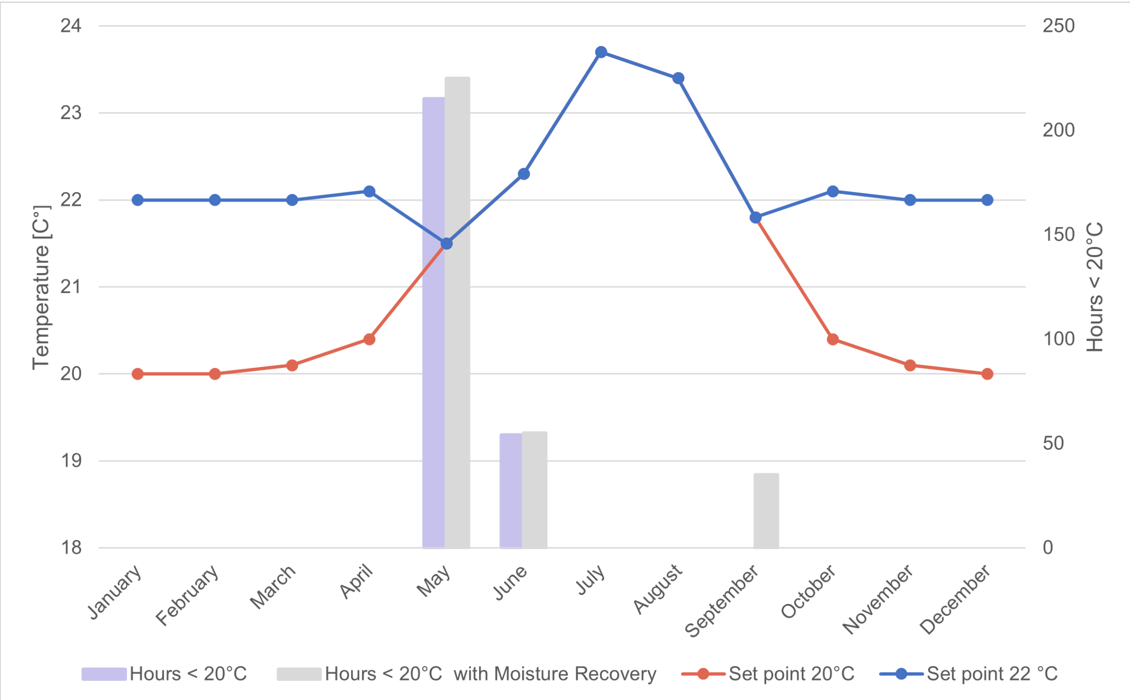


Figure 9.12: Mean temperature and number of hours below 20°C throughout the year for Traditional system with ventilation unit without moisture recovery for working couple

9.2.3.3 Moisture Levels

This section will introduce the results of simulations for the moisture level in the apartment. Figure 9.13 illustrates the relative humidity for the traditional system for both temperature set points 20°C (orange shades) and 22°C (blue shades).

The average relative humidity for a set point of 20°C for the whole year stays within the recommended range of 25%-60% with the lowest value recorded in March with an average of 25%. With the use of moisture recovery the humidity level is significantly higher and for the lowest level in March stays on average at 38.9%. For 22°C, the average humidity for January, February, and December remains slightly below the minimum of the recommended range and for March it is below that level. When the ventilation unit with moisture recovery was used the simulations recorded the rise of average RH to the minimum level of 32%. The use of the ventilation unit with moisture recovery helps to improve the relative humidity by up to 49% when the set point is 20°C. and up to 39% for 22°C.

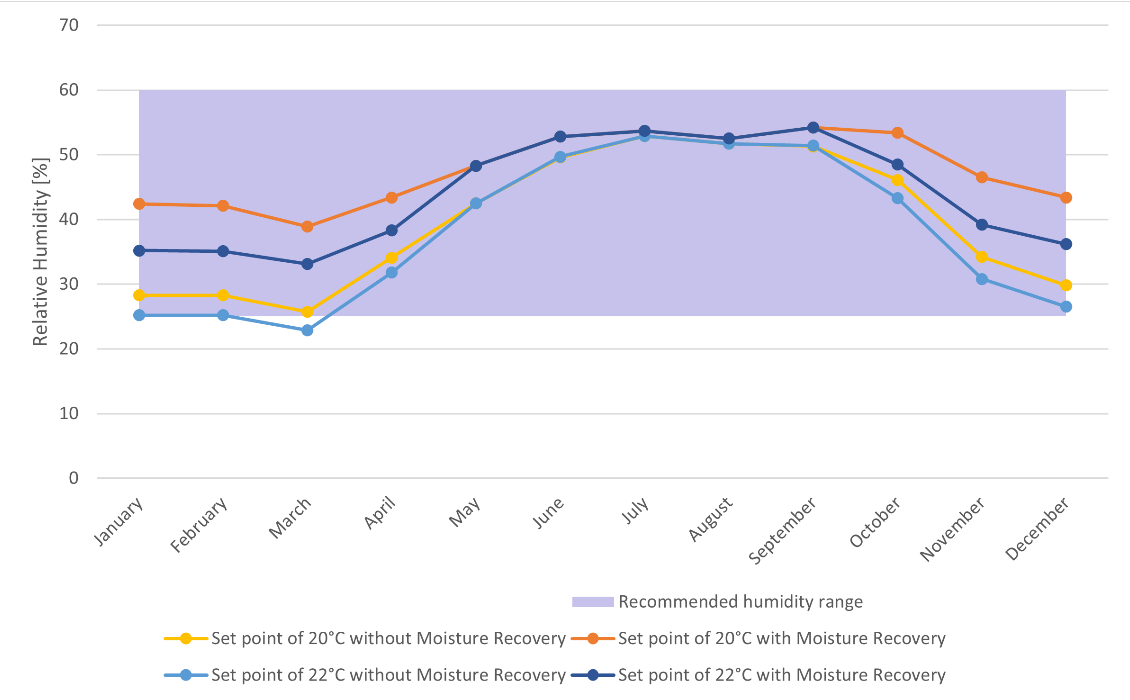


Figure 9.13: Relative humidity for traditional system for working couple

The second Figure 9.14 illustrates the moisture level for the HVV system. The general tendency remains the same as for traditional systems, however, the average humidity for the heating season is lower for the HVV system and stays below the recommended range for the temperature of 22°C. Also when it comes to the improvement of humidity level it is lower than for the traditional systems, and for both set points can be improved by up to 33%.

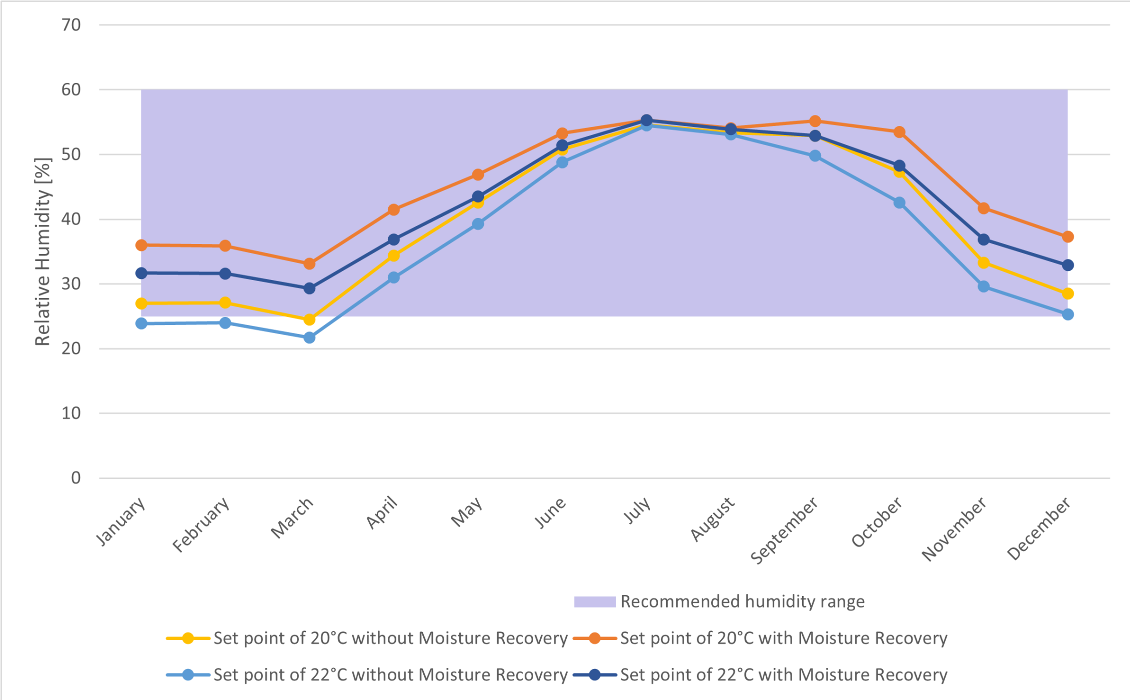


Figure 9.14: Relative humidity for the HVV system for working couple

Additionally, to the yearly results, it was decided to simulate the more detailed Humidity level for a shorter period. In this case, March was selected, as it had the lowest level. Figure Z presents the results of the mentioned simulation.

9.2.4 CO^2 level

For this scenario, the average monthly CO^2 level remains between 430 and 477ppm for traditional systems, and for HVV systems it is between 420 and 445ppm throughout the year,

Chapter 10

Comperative analysis

Based on the findings presented in the previous chapter, this section will now undertake a comparative analysis of both systems. The chapter is structured into two sections for temperature set points of 20°C and 22°C. In the previous chapter, we introduced variants with two different set point temperatures: 20°C and 22°C. For the comparative analysis chapter, both set point will be utilized. Higher set of 22°C has been calculated to be the optimal operative temperature for this environment and 20°C was calculated to be minimum comfortable temperature. The presentation of the 20°C set point was included to observe the indoor environment's response to a lower temperature. Each section will have three subsections: baseline, elderly couple, working couple. The design of this chapter facilitates a comparative analysis between the traditional system and HVV System within each specified scenario.

10.1 Set point: 20°C

10.1.1 Simulation for design temperatures without occupants or heat gains

10.1.1.1 Energy performance

As seen in Figure 10.1 below, the energy used for both the fan and heating components is compared for the two systems, with and without moisture recovery. It is evident that when considering the total energy use the traditional system without moisture recovery is the most efficient, while the HVV system with moisture recovery performs the worst in this comparison.

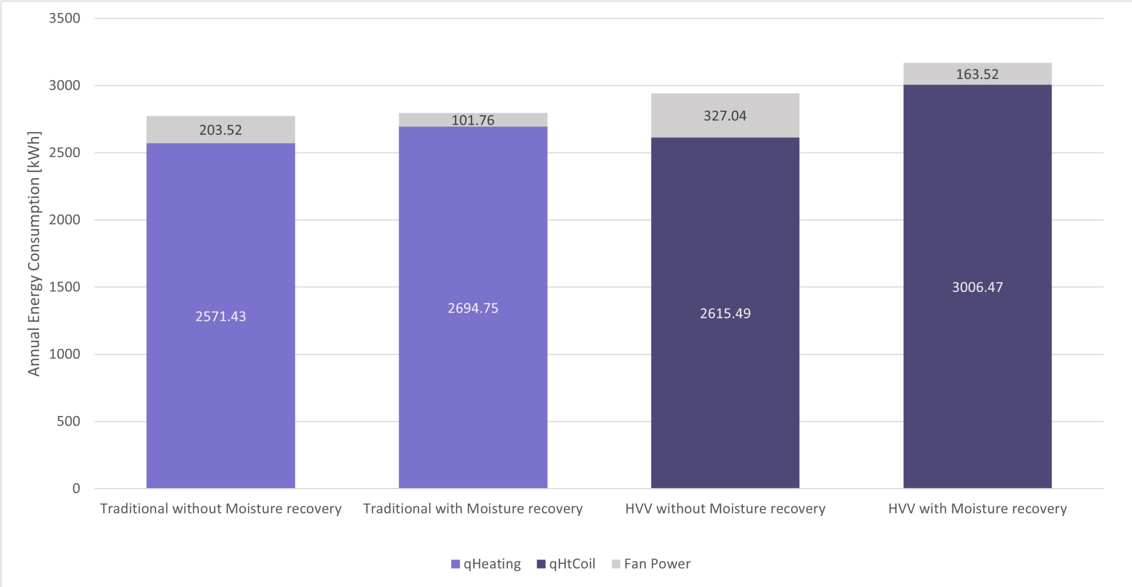


Figure 10.1: Energy performance of the traditional system and HVV at a set point of 20°C with no heat gains

10.1.1.2 Thermal Comfort

All scenarios experience similar temperature trends across different months. However, the traditional system, both with and without moisture recovery, experiences higher temperature deviations. Notably, a larger dip in May and a higher peak in July. However, during the heating season all scenarios maintain the set point of 20°C. The use of the ventilation unit with moisture recovery and lower heat recovery does not show a significant impact on thermal comfort across these scenarios.

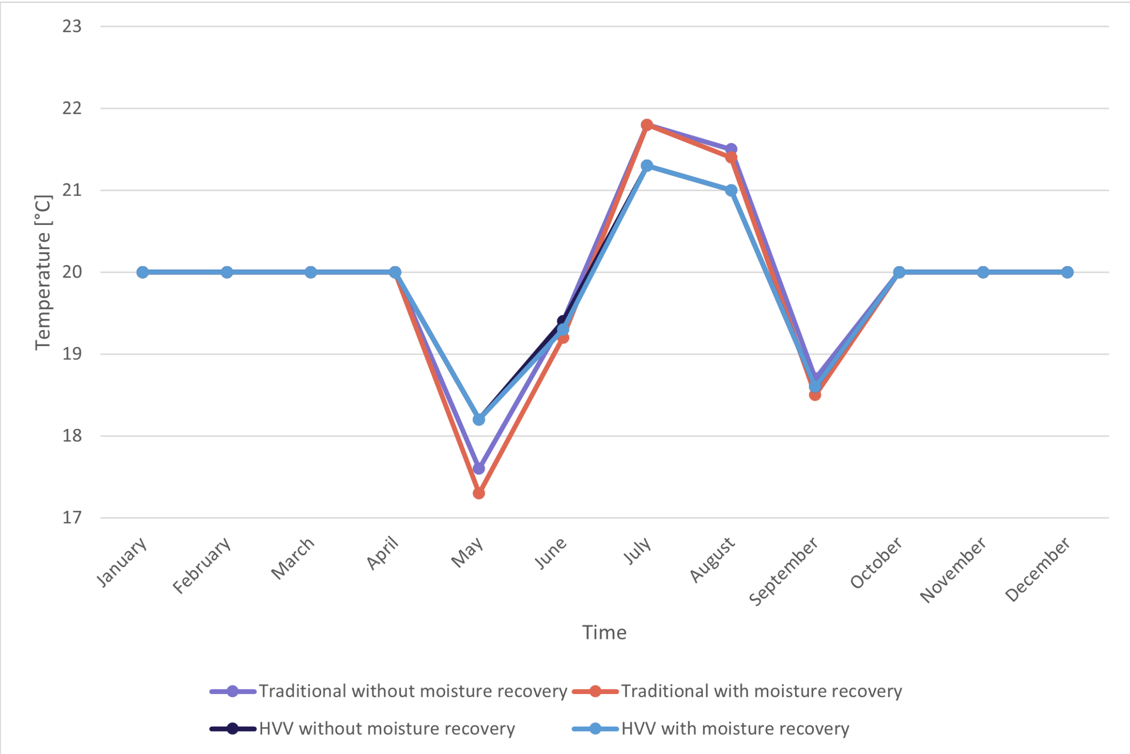


Figure 10.2: Mean temperature for traditional and HVV system for 20°C with no heat gains

10.1.1.3 Moisture levels

Across all scenarios, the relative humidity drops below the comfortable range from January to March, with a small dip observed in March. During summer months, the HVV systems, both with and without moisture recovery, show slightly elevated moisture levels, slightly exceeding the comfort range and having marginally higher values than the traditional system. However, these differences are minor and may not have a significant impact on the indoor environment. The examination of moisture levels across different scenarios shows that the presence of moisture recovery when there are no occupants or any other moisture sources seems to have a limited impact on overall moisture levels.

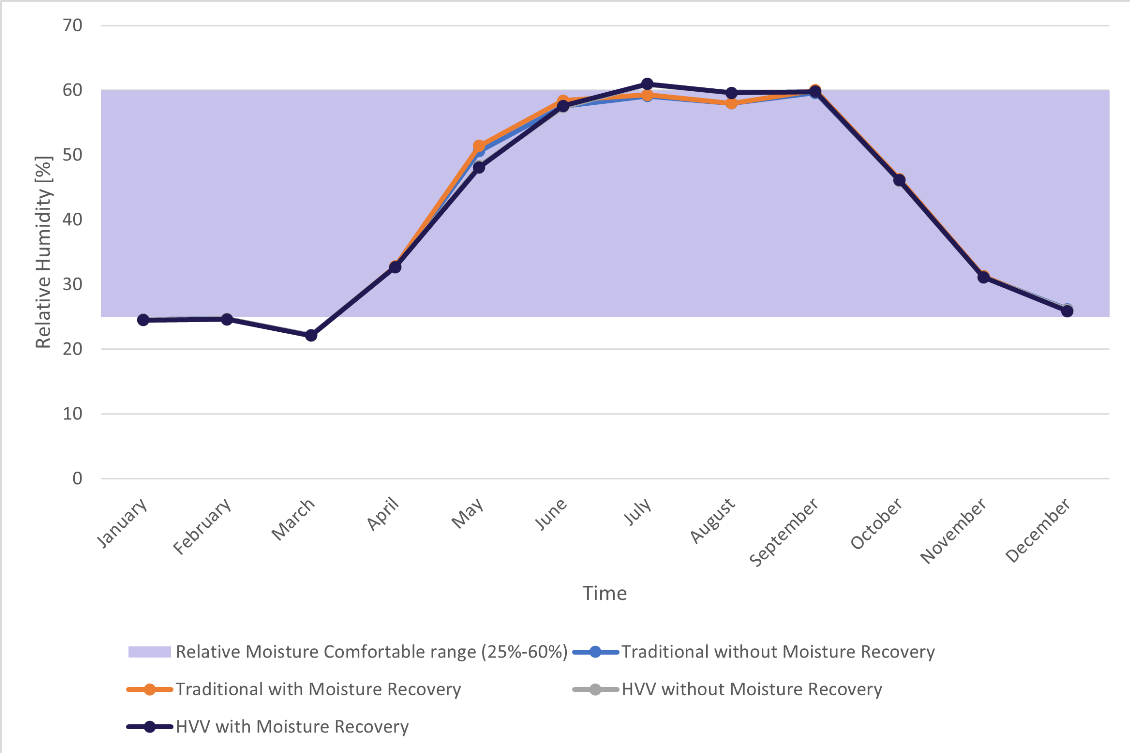


Figure 10.3: Moisture levels for traditional and HVV system for 20°C with no heat gains

10.1.2 Simulation for elderly couple

10.1.2.1 Energy performance

In the context of an elderly couple occupying the space, the energy needed for heating the spaces is smaller than in the baseline scenario, which is attributed to the heat produced by the occupants and equipment. It can be observed that the traditional system without moisture recovery performs as the most energy-efficient option. The presence of moisture recovery shows increased energy consumption. The HVV systems, with or without moisture recovery, consume more energy for heating compared to traditional systems.

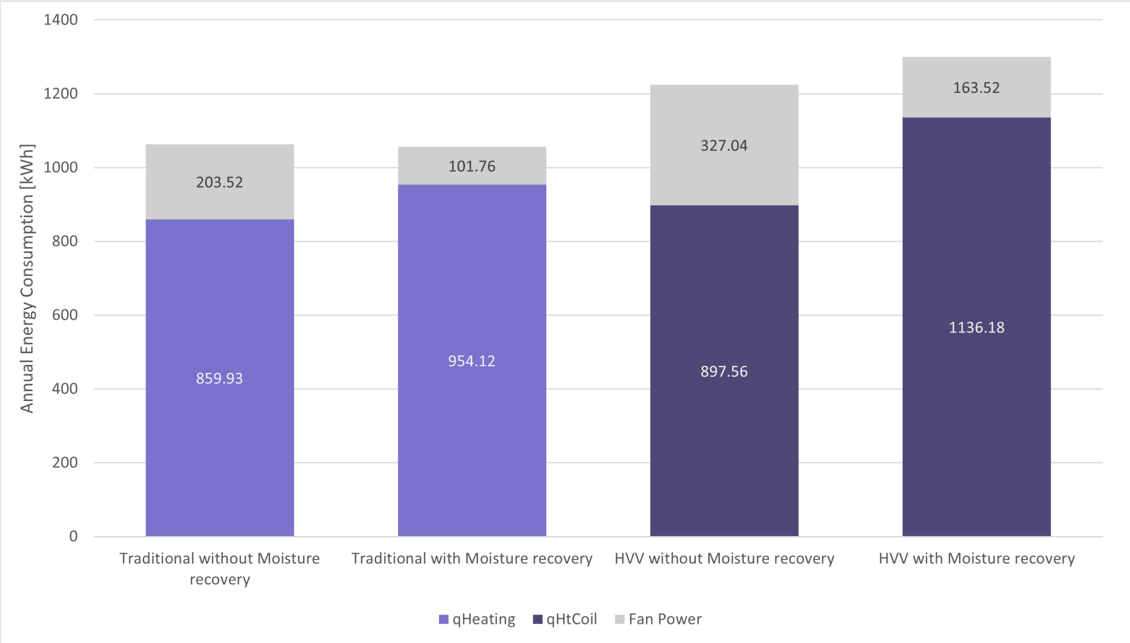


Figure 10.4: Energy performance of the traditional system and HVV at 20°C for elderly couple

10.1.2.2 Thermal Comfort

Across all scenarios, the mean temperature consistently stays above the set point temperature of 20°C, when an elderly couple is occupying the apartment. All scenarios exhibit a temperature rise in spring, reaching a peak in July, and a decrease in temperatures in autumn, aligning with typical seasonal patterns. There are slightly higher temperatures observed during non-heating periods when traditional systems are used. The difference in the temperatures is caused by the higher supply of airflow. Notably, moisture recovery does not have a significant influence on temperatures.

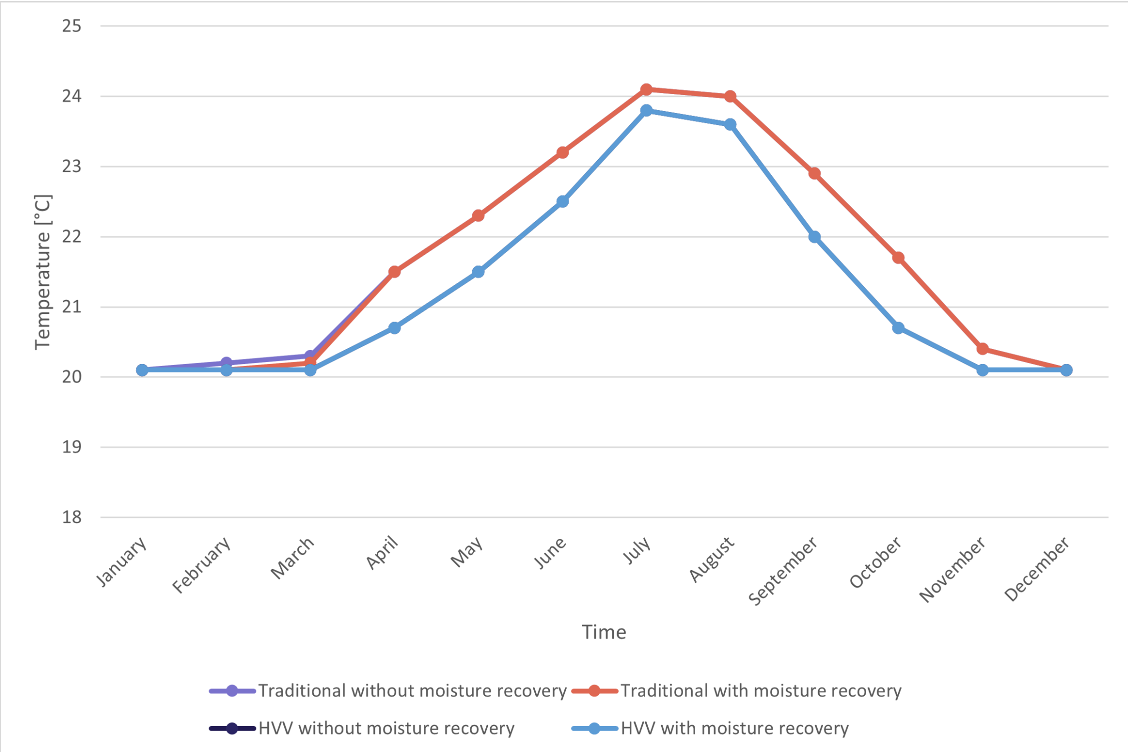


Figure 10.5: Mean temperature for traditional and HVV system for 20°C for elderly couple

10.1.2.3 Moisture levels

The analysis of moisture levels in the scenario with an elderly couple shows that all systems, except HVV without moisture recovery, remain within the comfort range. Traditional systems with moisture recovery demonstrate the best performance in terms of humidity levels in this comparison. Overall, the presence of moisture recovery is beneficial in achieving and maintaining comfortable humidity levels in the apartment. Because of the different efficiency of moisture recovery for the traditional and HVV systems which are respectively 0.91 and 0.86 the possibility of improvement is different. For the traditional system, the moisture was improved by up to 46% while in the HVV system, it was by around 30%.

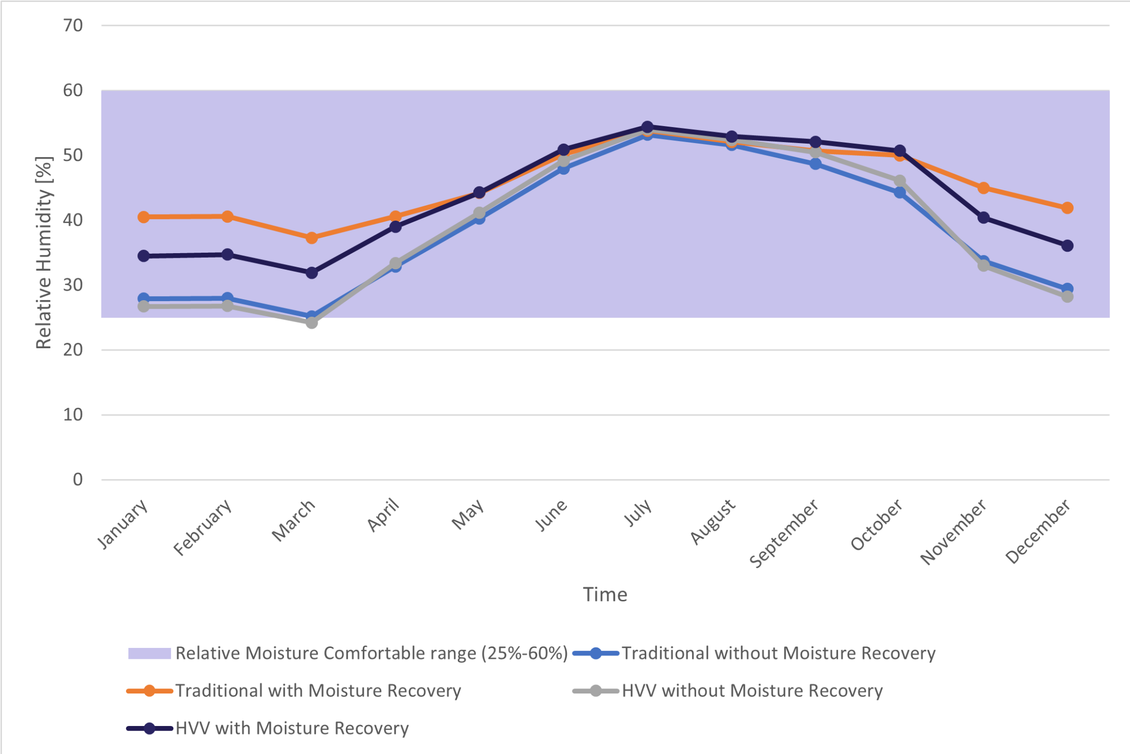


Figure 10.6: Moisture levels for traditional and HVV system for 20°C for elderly couple

10.1.2.4 CO2 Concentration

According to the figure below, CO2 concentrations remain consistent, and the levels are within acceptable ranges, indicating that there is no significant issue with indoor air quality related to CO2 throughout the year. However, one can observe that the HVV system has a better performance compared to the traditional system, likely due to its larger airflow, which contributes to better air quality.

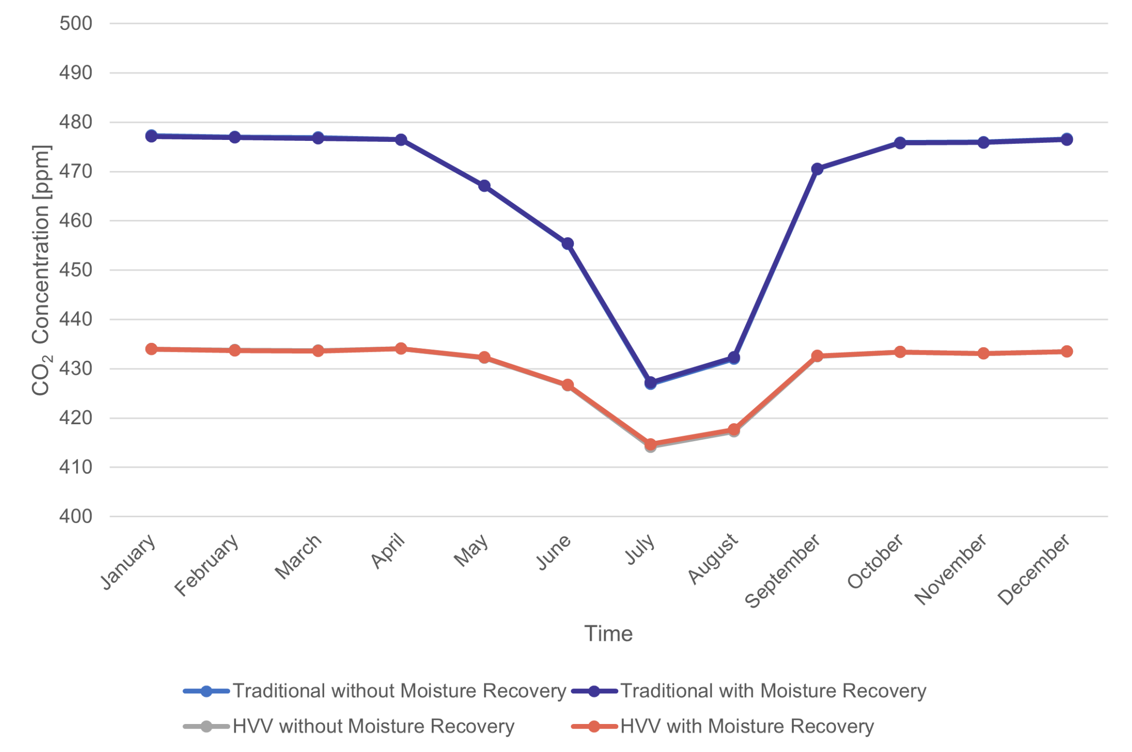


Figure 10.7: CO^2 concentration for traditional and HVV system for 20°C for working couple

10.1.3 Simulation for working couple

10.1.3.1 Energy performance

When a working couple is occupying the apartment the total energy consumption is slightly higher compared to the previous scenario with an elderly couple. This increase is attributed to the fact that two working individuals spend less time at home, resulting in smaller heat gains within the apartment. In general, the figure below reveals that systems are performing almost identically as it was in the previous section with elderly couples. The HVV system consumes more energy for heating and fan in both scenarios, making the traditional system a more energy-efficient option.

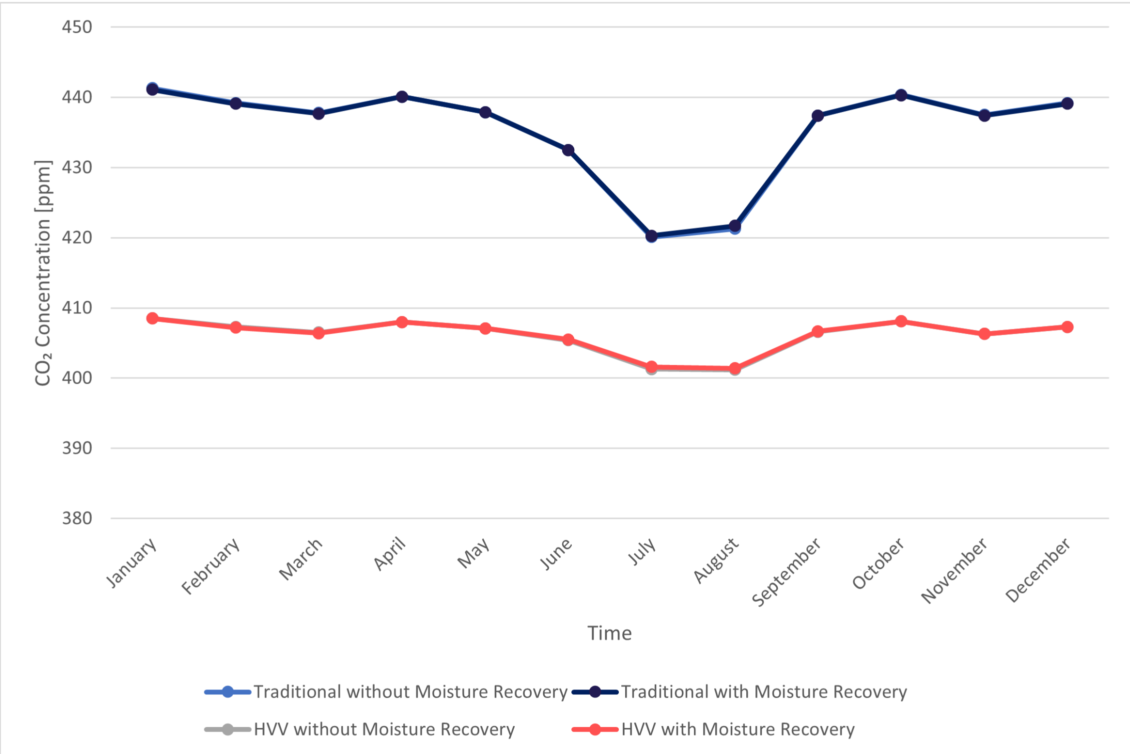


Figure 10.8: Energy performance of traditional system and HVV at a set point of 20°C for working couple

10.1.3.2 Thermal Comfort

In the scenario with a working couple mean temperatures are consistently at least at the set point. Similar to a scenario with elderly couples, there is a rise in temperatures during spring with a peak in July and a decrease in autumn. Traditional systems generally experience higher temperatures compared to the HVV systems, especially outside the heating season.

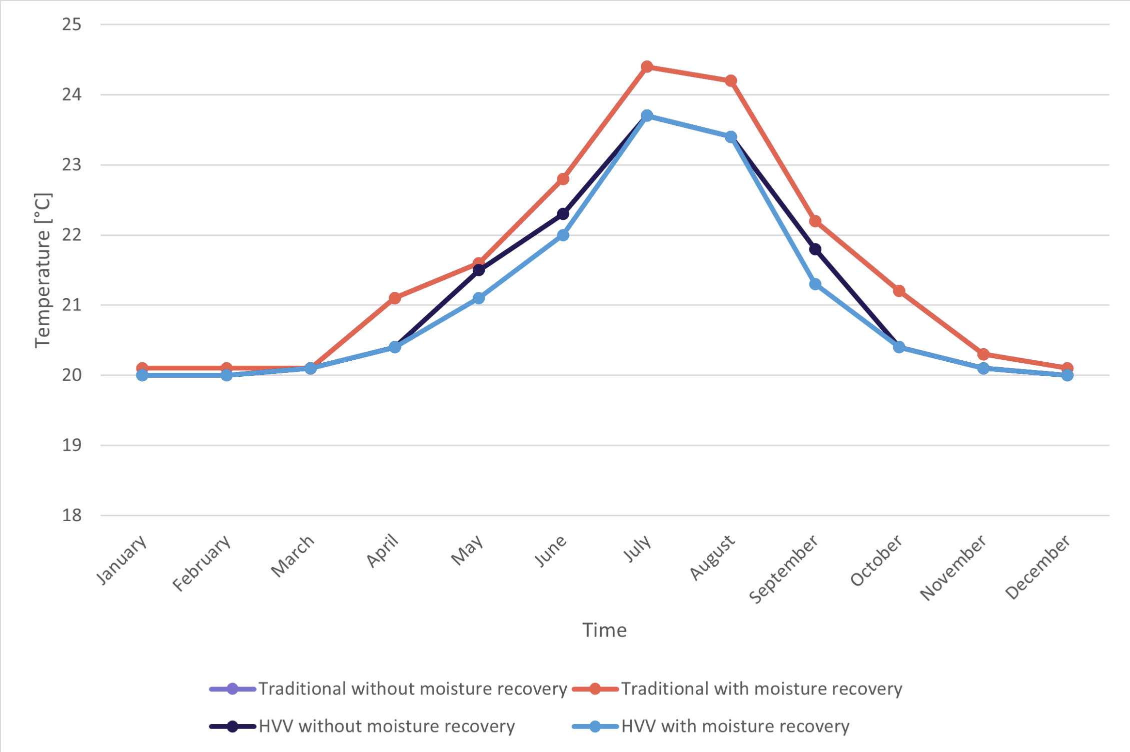


Figure 10.9: Mean temperature for traditional and HVV system for 20°C for working couple

10.1.3.3 Moisture levels

Moisture levels for working and elderly couples are nearly the same. In the figure below, presenting moisture levels thought the year it is evi all systems, except for air-based systems without moisture recovery, stay within the comfort range. Lack of moisture recovery results in lower humidity, causing a dip below the comfort range in March. Traditional systems with moisture recovery perform the best, highlighting its overall benefits for maintaining optimal indoor humidity.

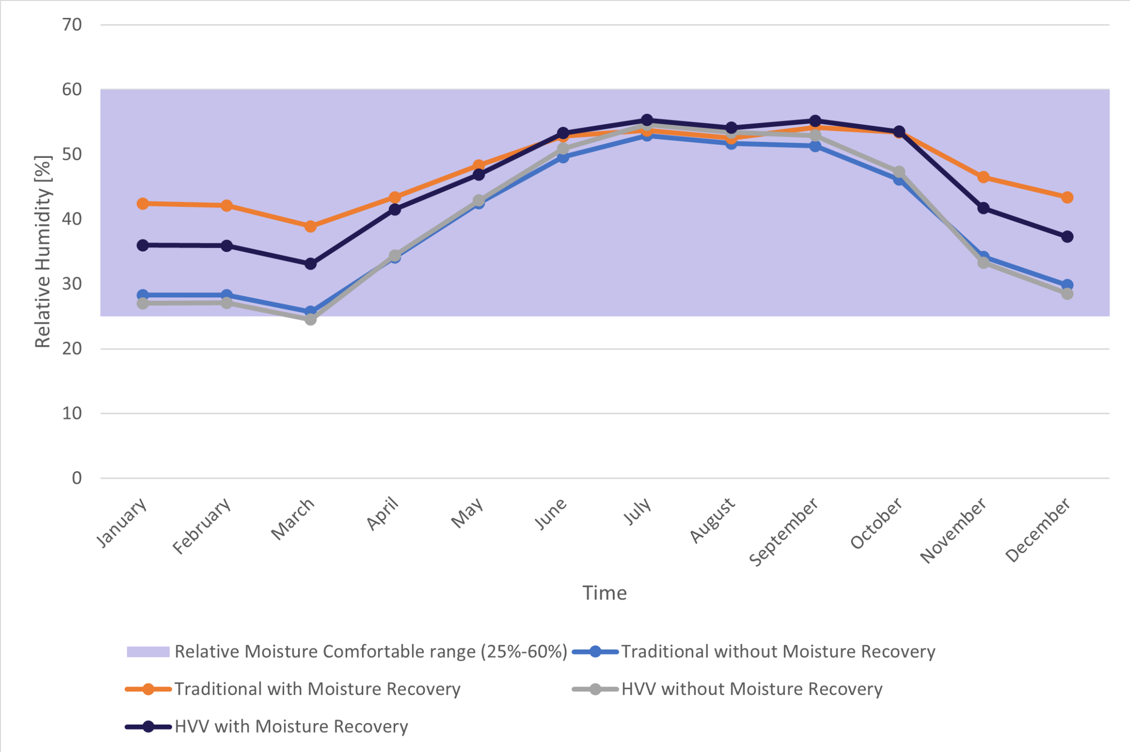


Figure 10.10: Moisture levels for traditional and HVV system for 20°C for working couple

10.1.3.4 CO^2 Concentration

CO^2 levels for working and elderly couples are similar and consistently within acceptable ranges, suggesting no significant indoor air quality issues throughout the year. The HVV system outperforms the traditional system, likely due to its higher airflow, contributing to better air quality.

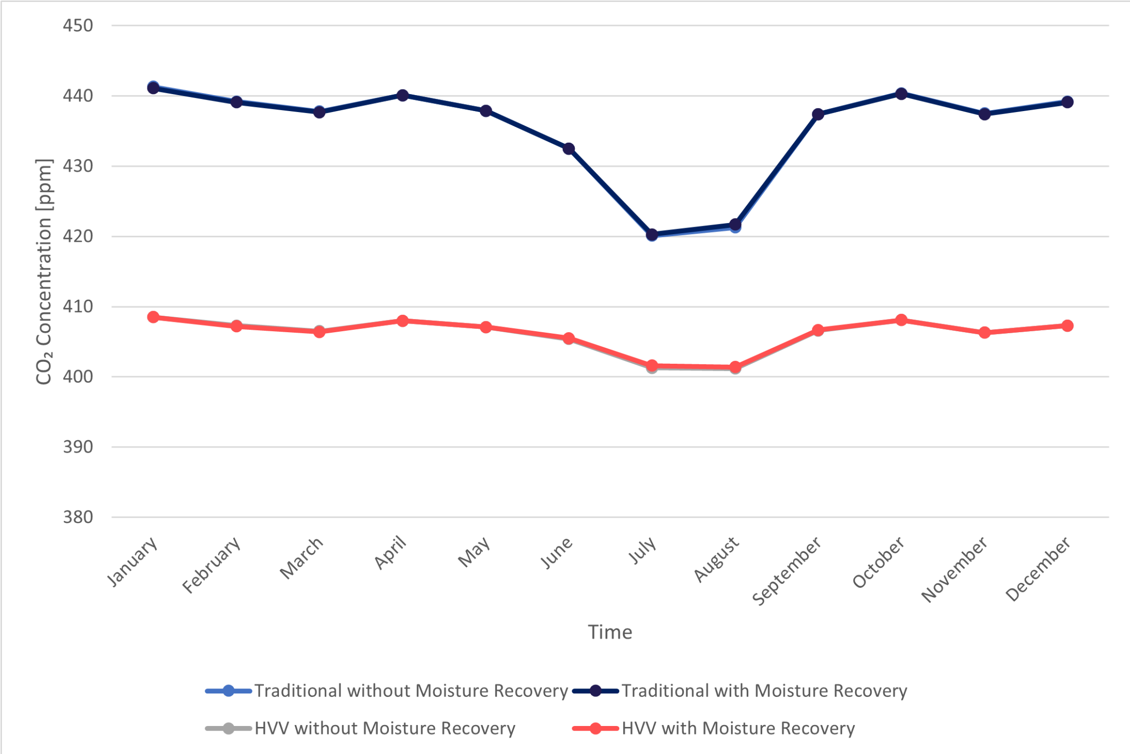


Figure 10.11: CO^2 Concentration for traditional and HVV system for 20°C for working couple

10.2 Setpoint 22

10.2.1 Simulation for design temperatures without occupants or heat gains

In this section, we present a comparative analysis between the traditional heating and mechanical ventilation system and the HVV system with set point of 22°C. This section aims to assess the yearly energy consumption, thermal comfort, CO^2 and moisture levels of both systems under a scenario with no people or equipment load.

10.2.1.1 Energy performance

One of the primary parameters evaluated was the energy consumption of each heating system. The simulation tracked the energy usage patterns over the course of the year.

While there is an slight increase in fan power by Heat Valve Ventilation System, the overall energy efficiency of the HVV system shows that total yearly energy consumption is slightly lower when moisture recovery is not applied and insignificantly higher when moisture recovery is present. Based on those findings it can be seen that both systems perform almost identically and there is marginal difference in the total annual energy consumption in case where there is no additional heat loads.

For better understanding of the comparative analysis, a side-by-side evaluation of the energy consumption of both systems is presented in Figure 10.12:

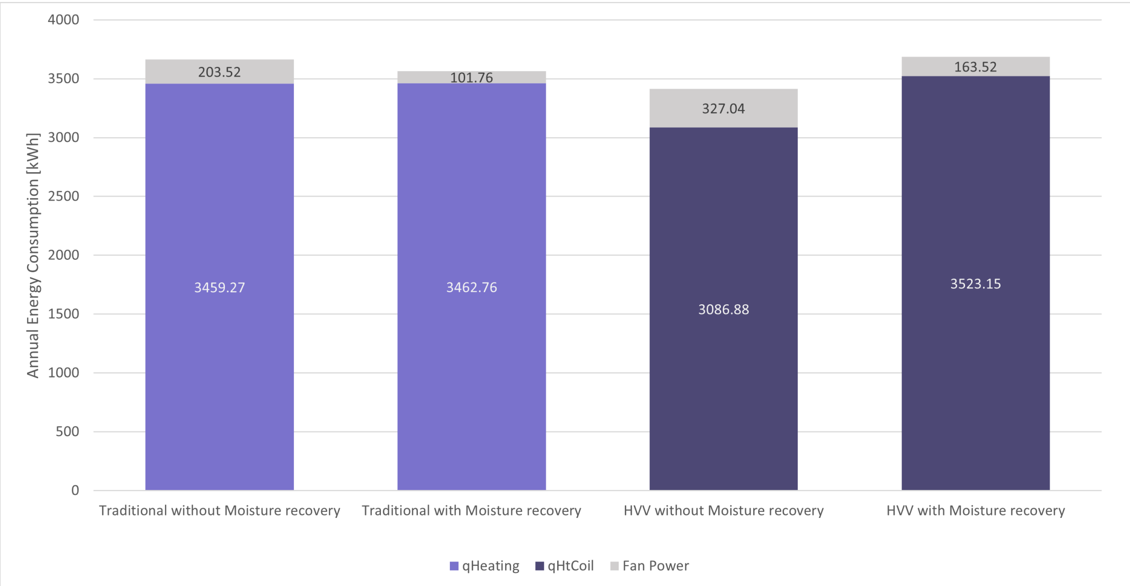


Figure 10.12: Energy performance of traditional system and HVV at set point of 22°C with no heat gains

10.2.1.2 Thermal comfort

This section focuses on evaluating the thermal comfort provided by both systems. Thermal comfort is an important aspect of indoor environment, and this section evaluate how each system performs with no occupants present in the building across different months.

Hours below 20°C Celsius are omitted in the comparative analysis chapter, as the recorded hours primarily occur during the summer, which is not the focus of this research.

To illustrate the results, the mean monthly temperatures for set point of 22 degrees Celsius for both systems are presented in Figure 10.13 below:

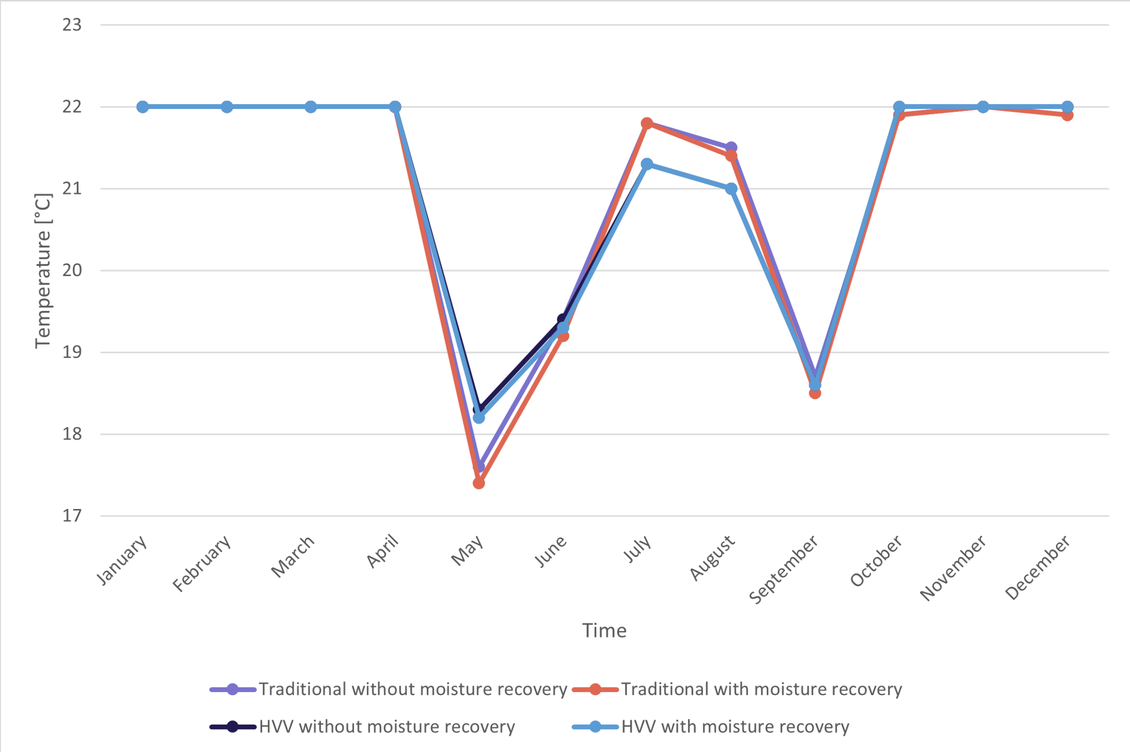


Figure 10.13: Mean temperature of traditional system and HVV at set point of 22°C with no heat gains

The figure illustrates that during the winter period, the temperature remains at the set point. However, in May and September, the temperature in both systems drops below the set point. It is noticeable that HVV System experiences a more significant dip than the traditional system. Additionally, in July and August, the temperature in the traditional system reaches above 22°C, while HVV System remains below that. The presence of moisture recovery shows marginal differences in both systems, and it can be observed that the mean temperature is minimally lower with moisture recovery.

10.2.1.3 Moisture Levels

In this section, moisture levels within the apartment for both the traditional heating and mechanical ventilation system and the HVV system are compared. The comparison will provide better understanding how each system manages moisture under conditions where there is no occupants or additional gains. To provide a detailed comparison, the moisture levels for each month are presented in Figure **??** below:

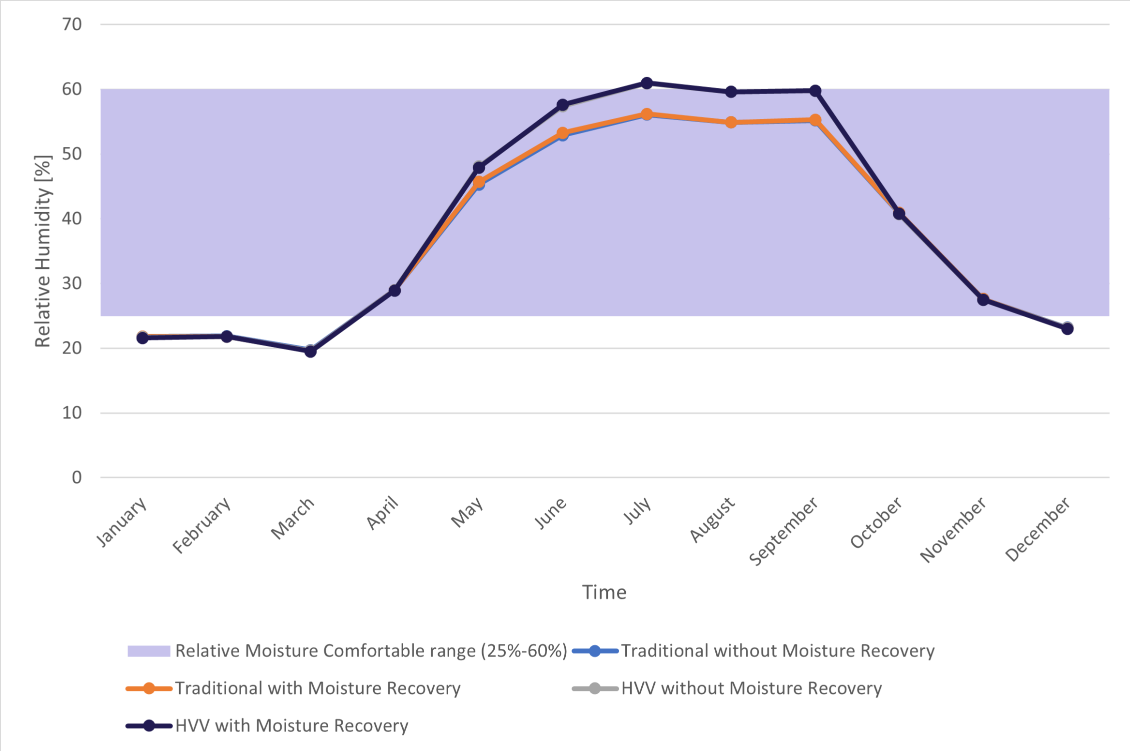


Figure 10.14: Moisture levels of traditional system and HVV at set point of 22°C with no heat gains

Both systems show similar levels throughout the year. However, specific variations are noted during summer period. From June to September, the HVV system experiences slightly higher moisture levels. The moisture levels fall below the comfortable range from December to April. The is no significant difference when the ere is ventilation unit with moisture recovery or without.

10.2.2 Simulation for elderly couple

This section focuses on comparing the traditional heating and mechanical ventilation system with the HVV system in the context of an apartment occupied by an elderly couple.

10.2.2.1 Energy performance

As seen in Figure 10.15, in the case of the system with a ventilation unit without moisture recovery the Heat valve ventilation system has a better performance than traditional in context of total energy consumption as well as the energy used for heating. When a unit with moisture recovery is used and the temperature efficiency of the unit is lower the traditional system has a better performance.

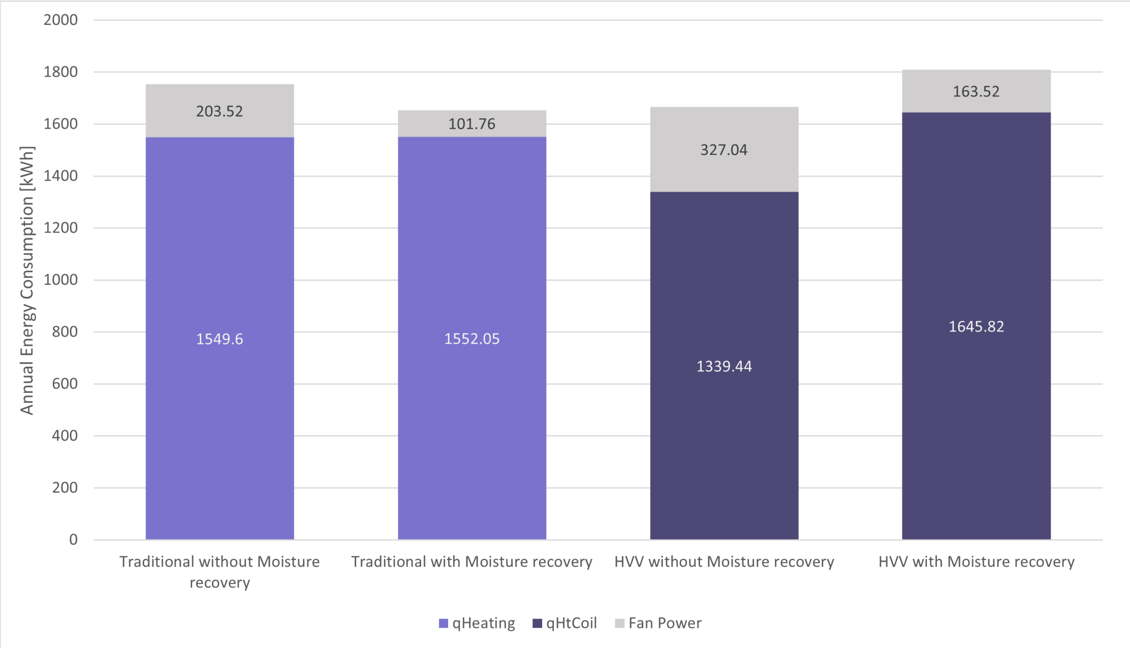


Figure 10.15: Energy performance of traditional system and HVV at set point of 22°C for elderly couple

10.2.2.2 Thermal comfort

When considering the mean temperatures over the year, no difference is evident in choice of ventilation unit, whether equipped with or without moisture recovery. Both systems experience similar patterns throughout the year. However, the traditional system consistently maintains temperatures above the set point throughout the year, whereas HVV remains at the set point during the heating season. Additionally, the traditional system shows slightly higher temperatures during the summer months.

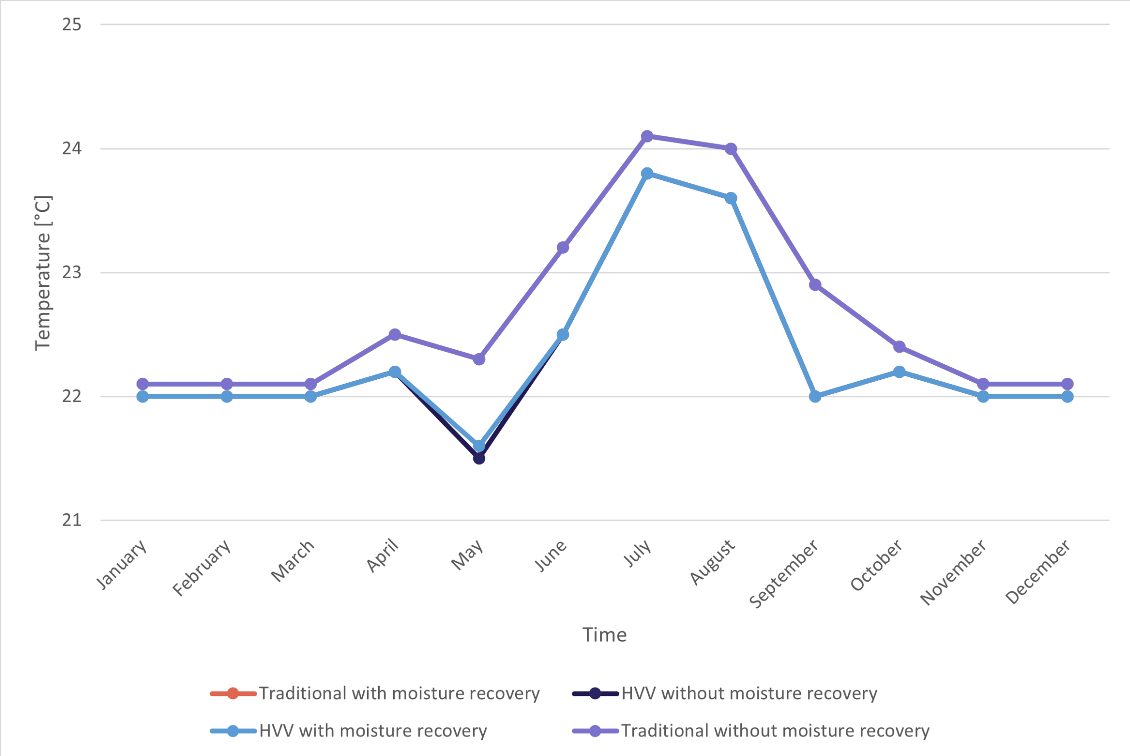


Figure 10.16: Mean temperature of traditional system and HVV at set point of 22°C for elderly couple

10.2.2.3 Moisture Levels

The figure below shows moisture levels throughout the year for various scenarios when working couple is occupying the apartment. As visible, in all cases, the patterns are similar, with higher relative humidity in summer months and lower in winter. During the winter period, differences between scenarios are notably more visible than in the summer months. The absence of moisture recovery in both systems results in recorded values falling below the comfortable range during winter. In terms of comparison, when moisture recovery is applied, the traditional system experience approximately 5% higher relative humidity than HVV system during the winter.

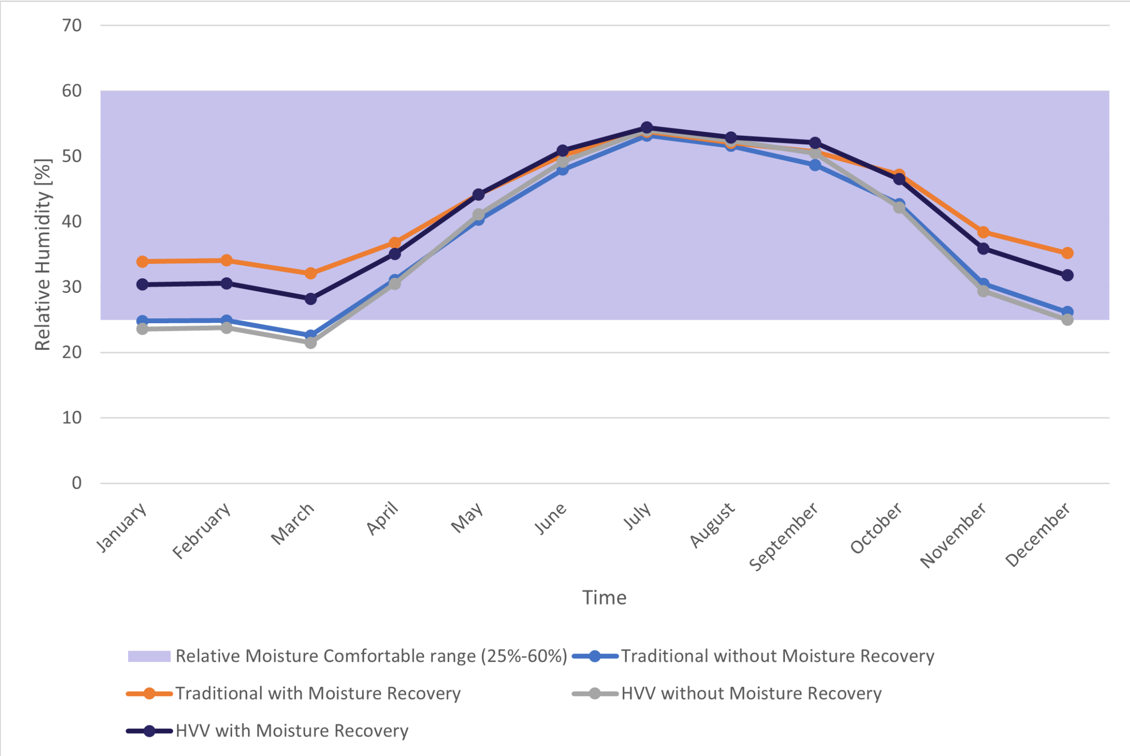


Figure 10.17: Moisture levels of traditional system and HVV at set point of 22°C for elderly couple

10.2.2.4 CO^2 Concentration

When evaluating a elderly couple and a set point of 22°C, there are no concerns regarding CO^2 concentration within the apartment compared to traditional systems. Consistent with earlier scenarios, HVV appears to handle CO^2 concentration slightly more effectively than its traditional systems.

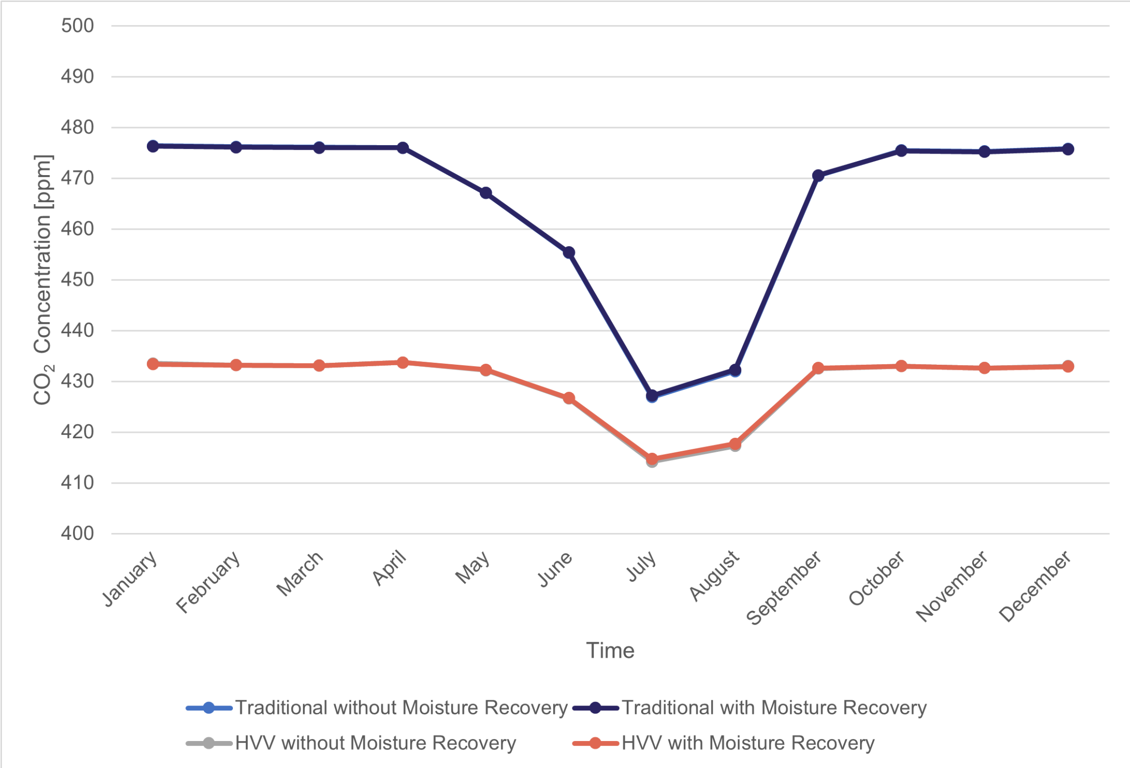


Figure 10.18: CO^2 concentration of traditional system and HVV at set point of 22°C for elderly couple

10.2.3 Simulation for working couple

This section, like the previous one, will analyze and compare simulation results but when the apartment is occupied by a working couple.

10.2.3.1 Energy performance

The figure below illustrates that the total energy consumption in the traditional system with moisture recovery is lower than in the case where the unit is not equipped with moisture recovery. On the other hand, in HVV system, the situation is opposite, with the system utilizing moisture recovery consuming more energy. In both scenarios, the fan in HVV system consumes more energy than in the traditional system. The total energy consumed by HVV system is slightly higher without moisture recovery and significantly higher when the system uses a ventilation unit with moisture recovery but lower heat recovery.

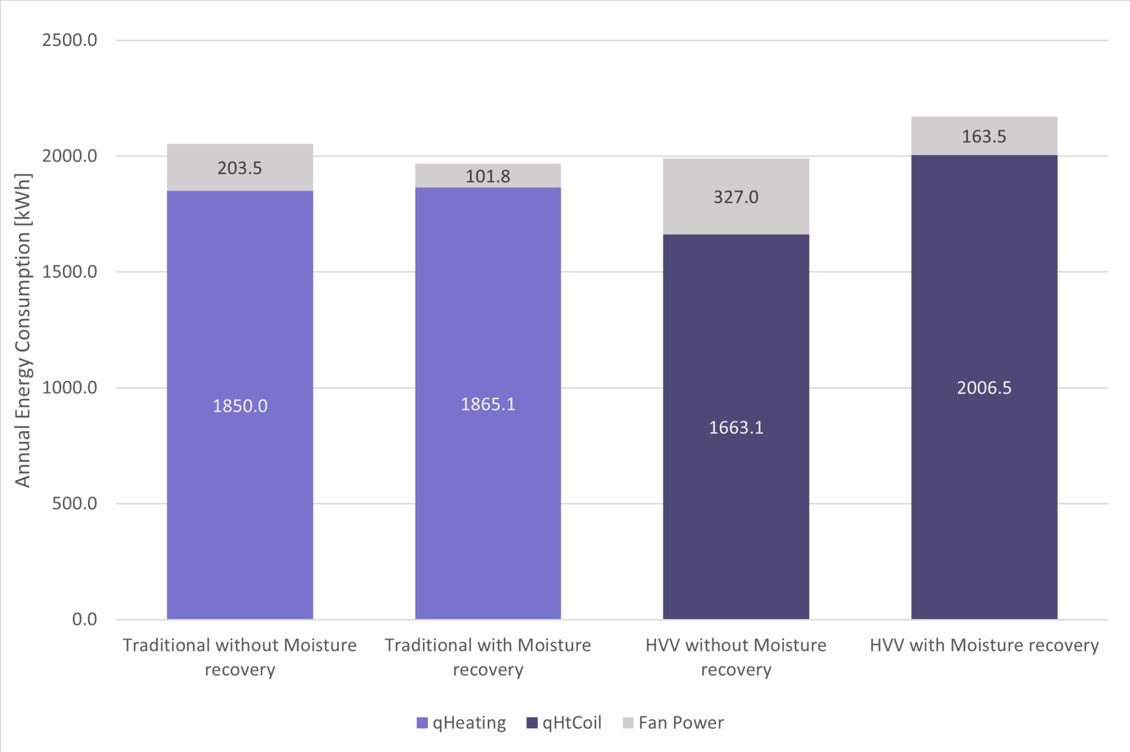


Figure 10.19: Energy performance of traditional system and HVV at set point of 22°C for working couple

10.2.3.2 Thermal comfort

When a working couple occupies the apartment, the scenario with the traditional system experiences higher temperature deviations from the set point. The traditional system exhibits a dip below the 22 °C in May and peaks in July and August, while HVV system remains more stable. Apart from May, in the case of the traditional system, temperatures remain above the set point for the entire year. There is no noticeable difference whether a unit with moisture recovery is present or not.

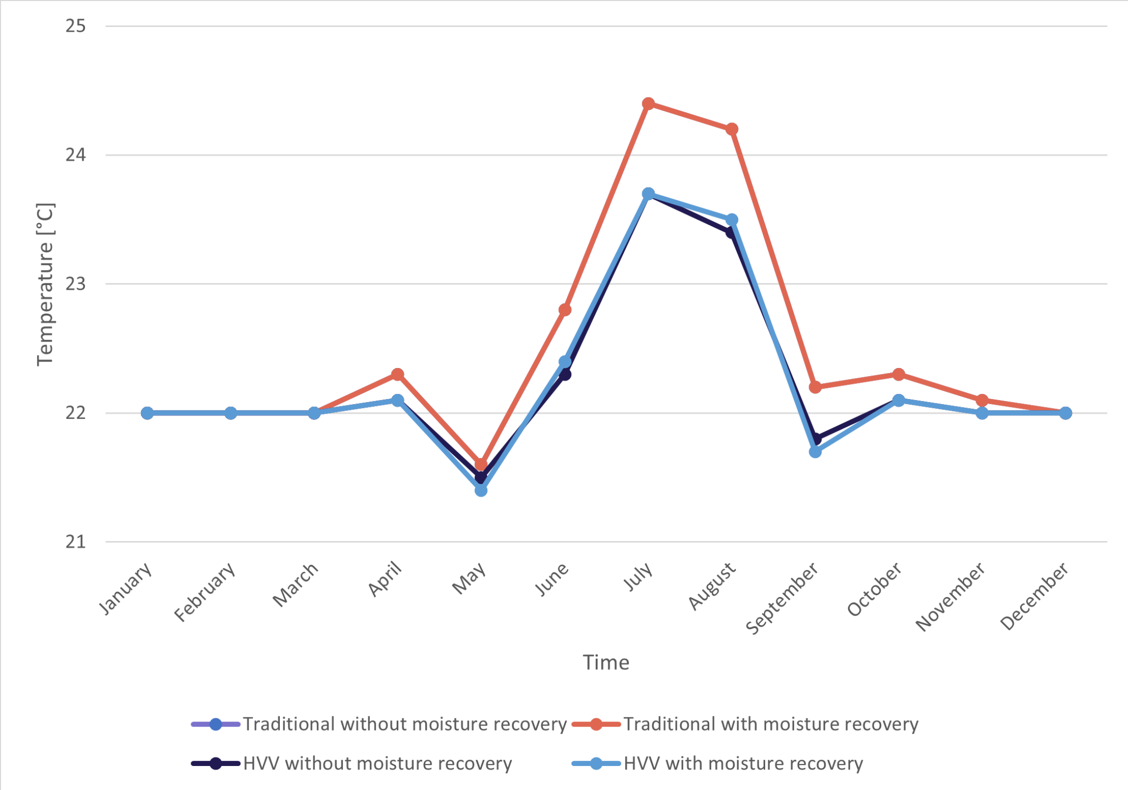


Figure 10.20: Mean temperature of traditional system and HVV at set point of 22°C for working couple

10.2.3.3 Moisture Levels

Regarding moisture levels, it is evident that both systems behave almost identically to the scenario with an elderly couple. Similar to the previous scenario, the traditional system records higher values during winter period. However in this case we can observe slightly higher moisture levels during summer when using HVV system. Additionally, it is observed that scenarios with units lacking moisture recovery fall below the comfortable range.

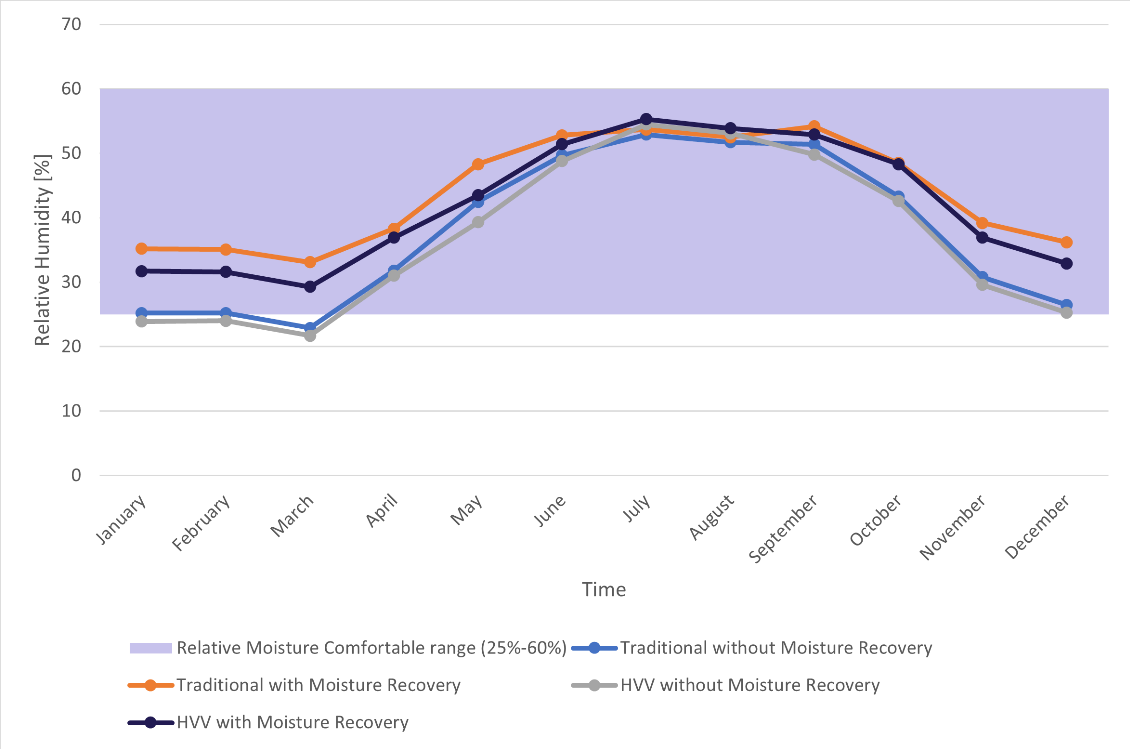


Figure 10.21: Moisture levels of the traditional system and HVV at set point of 22°C for working couple

10.2.3.4 CO^2 concentration

As illustrated in the figure below, when considering a working couple and a set point of 22°C, there are no issues concerning CO^2 concentration within the apartment in comparison to traditional systems. Similar to previous scenarios, HVV seems to manage CO^2 concentration slighty better comparing to traditional system.

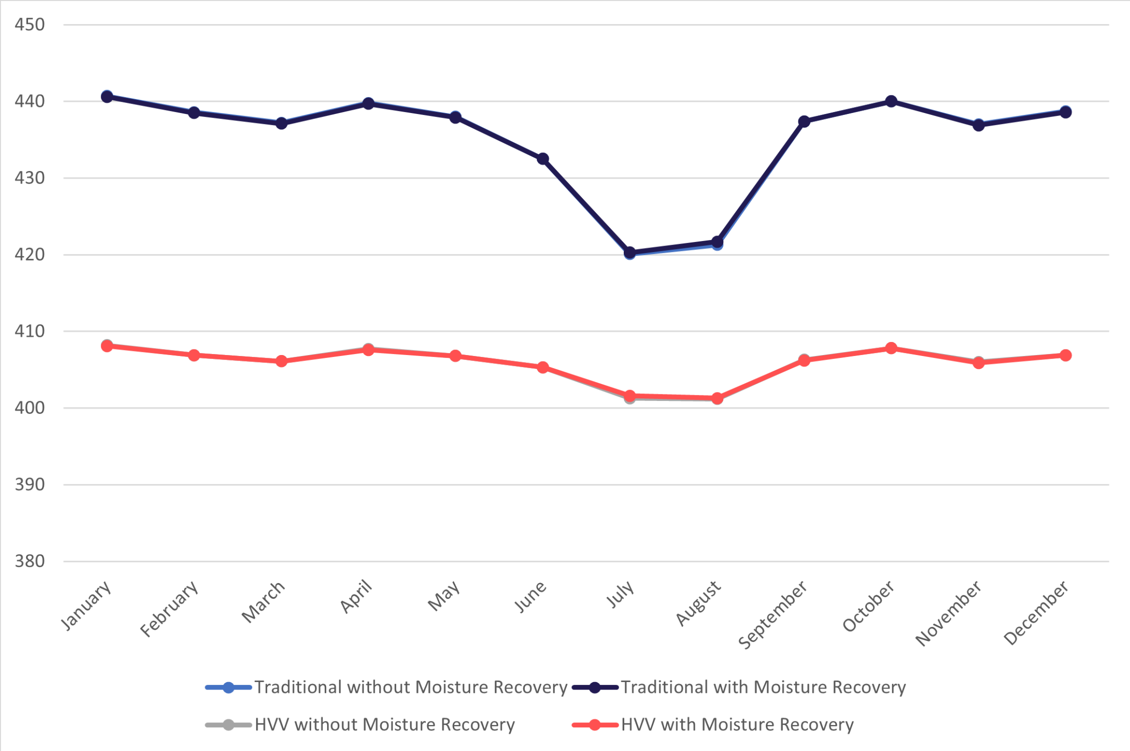
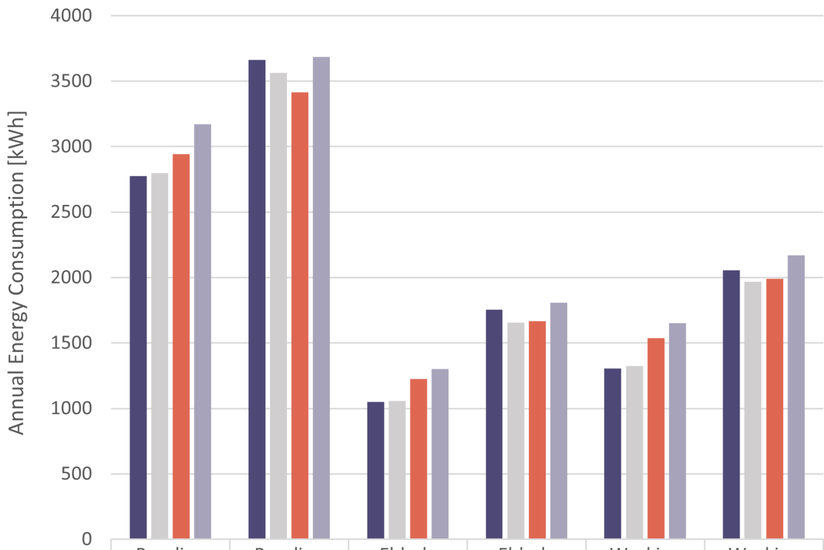


Figure 10.22: CO^2 concentration of traditional system and HVV at set point of 22°C for working couple

10.3 Summary

To conclude, a comprehensive analysis of two systems across different scenarios within an apartment, considering two set points of 20°C and 22°C, occupancy profiles of elderly, working couples, and no occupants, has analyzed systems performance in terms of energy efficiency, thermal comfort, moisture levels, and CO^2 concentration during the year. The analysis considered two ventilation units: a classic with higher heat recovery one with moisture recovery and a smaller heat recovery.

In terms of energy consumption, the HVV system generally performed worse when the set point was set to 20°C as evident in the figure below. However, for the higher set point of 22°C, the HVV system presented lower energy consumption in scenarios with no occupants. Also, results show that with units with lower heat recovery and moisture recovery, the traditional system turned out to be better in terms of energy consumption. The findings suggest that when the set point is increased to 22°C and a unit with higher heat recovery capabilities is used, the HVV system demonstrates better performance than a traditional system, enabling annual energy savings ranging from 3% to 7%.



	Baseline 20°C	Baseline 22°C	Elderly 20°C	Elderly 22°C	Working 20°C	Working 22°C
Traditional Without Moisture Recovery	2774.95	3662.79	1051.14	1753.12	1303.43	2053.52
Traditional With Moisture Recovery	2796.51	3564.52	1055.88	1653.81	1324.94	1966.9
HVV Without Moisture Recovery	2942.53	3413.92	1224.6	1666.48	1537	1990.2
HVV With Moisture Recovery	3169.99	3686.67	1299.7	1809.34	1651.5	2170

Figure 10.23: Annual Energy Consumption Comparison

Regarding thermal comfort, both systems consistently maintained comfortable temperatures across all scenarios. Notably, the traditional system exhibited higher temperatures outside the heating season in both set points. When it comes to moisture levels, both systems demonstrated similar results, staying within comfortable humidity levels for the majority of the time. The HVV, however, showed slightly lower humidity levels during the heating season. In terms of CO^2 levels, both systems maintained a comfortable range, however, the HVV system seemed to handle CO^2 concentration slightly better than a traditional system.

In summary, while both systems demonstrated satisfactory performance in thermal comfort, moisture levels, and CO^2 levels, noticeable differences were observed in energy consumption. The HVV system showed advantages in energy efficiency, only in scenarios with higher heat recovery and higher temperature set points.

Chapter 11

Life Cycle Assessment

11.1 Introduction

In this chapter, a Life Cycle Assessment was conducted to compare the environmental impact of two systems: A traditional Heating and ventilation system and a combined HVV system. The analysis is focused solely on the systems and installations, excluding other construction elements that would be identical in both cases. The operational energy use data was collected from results from BSim simulation results in each scenario, considering specific heat use and electricity consumption by fans in both systems. The scenarios considered for LCA include different set points of 20°C and 22°C and two AHU configurations: one without moisture recovery and higher heat recovery, and another with moisture recovery and lower heat recovery. The LCA was performed using the LCAbyg, and the life cycle of the building was considered over a 50 year period. The chapter is divided into three sections, where systems are compared with no occupants and with 2 occupancy profiles where elderly and working couple is occupying the apartment.

11.2 Results

The Global Warming Potential (GWP) was assessed for both systems, taking into account their respective operational energy use and system components. Results will be presented for each scenario and two set points of 20°C and 22°C. The LCA results for the traditional system and the HVVC system are presented below. The values represent the environmental impact for each system in CO2 emissions for Operation and Elements.

11.2.1 Baseline with 20°C set point

The LCA results for different configurations of both systems are presented below. The table below presents environmental impact scores for different configurations of traditional and HvV systems for set point of 20°C. The Operation column represents the total CO2 equivalent emissions associated with the operational phase of each HVAC system variation.

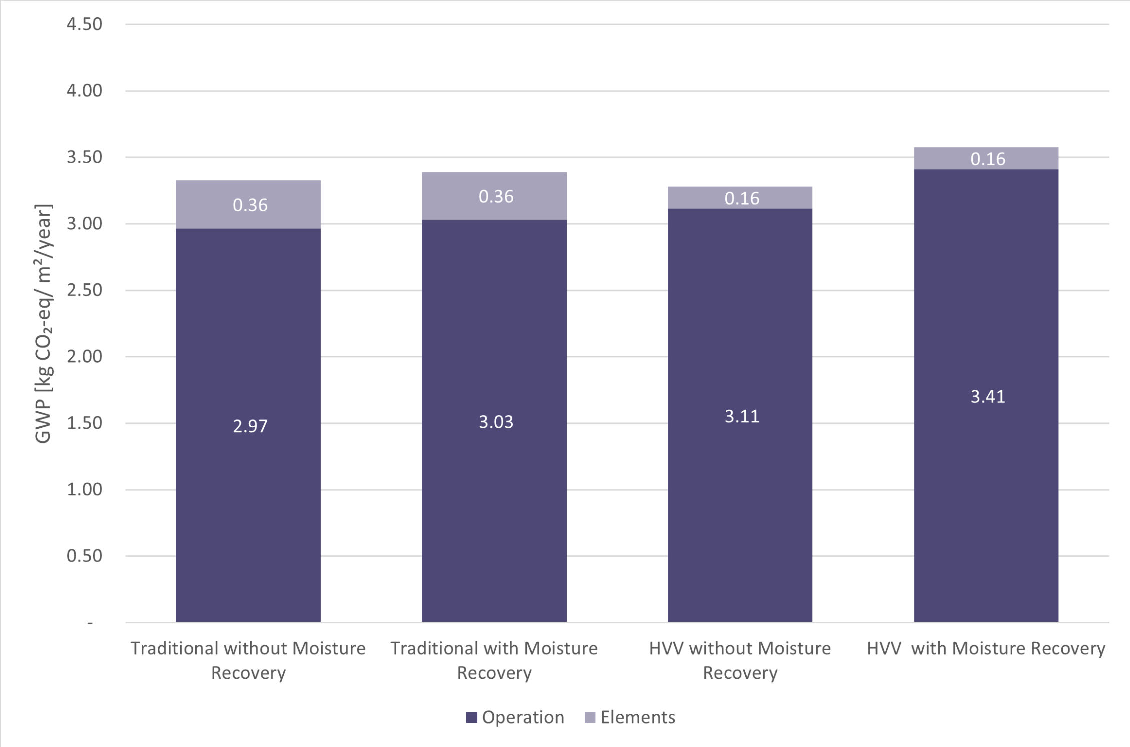


Figure 11.1: LCA results for baseline for set point of 20°C

Notably, the HVV system with moisture recovery has the highest operational impact at 3.55 CO_2eq/m2 per year. Operational impacts vary, with HVV systems generally having higher values. Moisture recovery influences both operational and life cycle impacts in HVV systems. Traditional system without moisture recovery has the lowest total impact at 3.33 CO_2eq/m2 per year. HVV system with moisture recovery has the highest total impact at 3.71 CO_2eq/m2 per year.

11.2.2 Baseline with 22°C set point

The figure below shows the environmental impact for different configurations of traditional and HVV systems, emphasizing a higher temperature set point of 22°C.

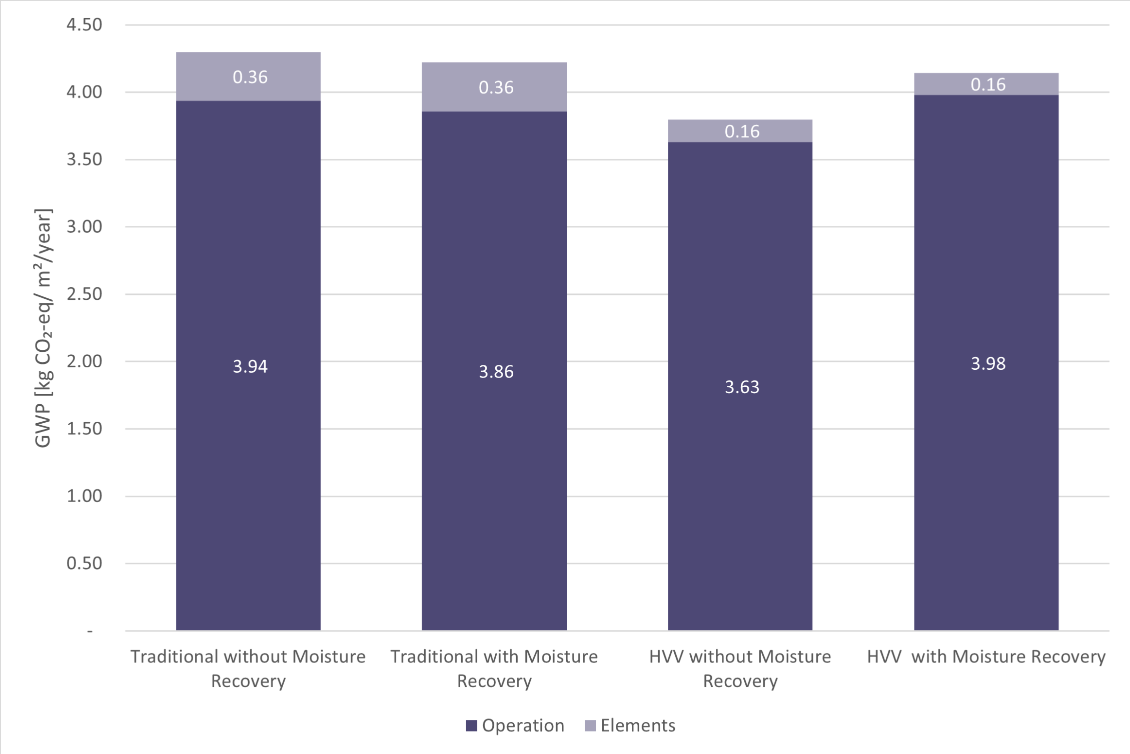


Figure 11.2: LCA results for baseline for set point of 22°C

It can be seen that Operational impacts increase across all systems at the higher set point. Moisture recovery has a consistent influence on both operational and life cycle impacts in both traditional and HVV systems. Notably, the temperature set point significantly affects operational and life cycle impacts. HVV systems, especially without moisture recovery, offer environmental advantages over traditional systems with set point of 22°C.

11.2.3 Elderly Couple with 20°C set point

The LCA results for system variations in a scenario where an elderly couple occupies the building at a set point of 20°C, shows that operational impact is significantly lower comparing to baseline due to heat produced by occupants. The traditional systems, both with and without moisture recovery, show slightly lower operational impacts, while having higher impact from elements. The analysis suggests that the HVV without Moisture Recovery option is relatively more energy-efficient compared to other system variations. This system demonstrates a lower operational impact of 1.24 CO_2eq/m2 per year, indicating more efficient energy use during the operational phase. The total environmental impact is 1.40 CO_2eq/m2 per year, which is lower compared to other options, considering both operational and life cycle impacts.

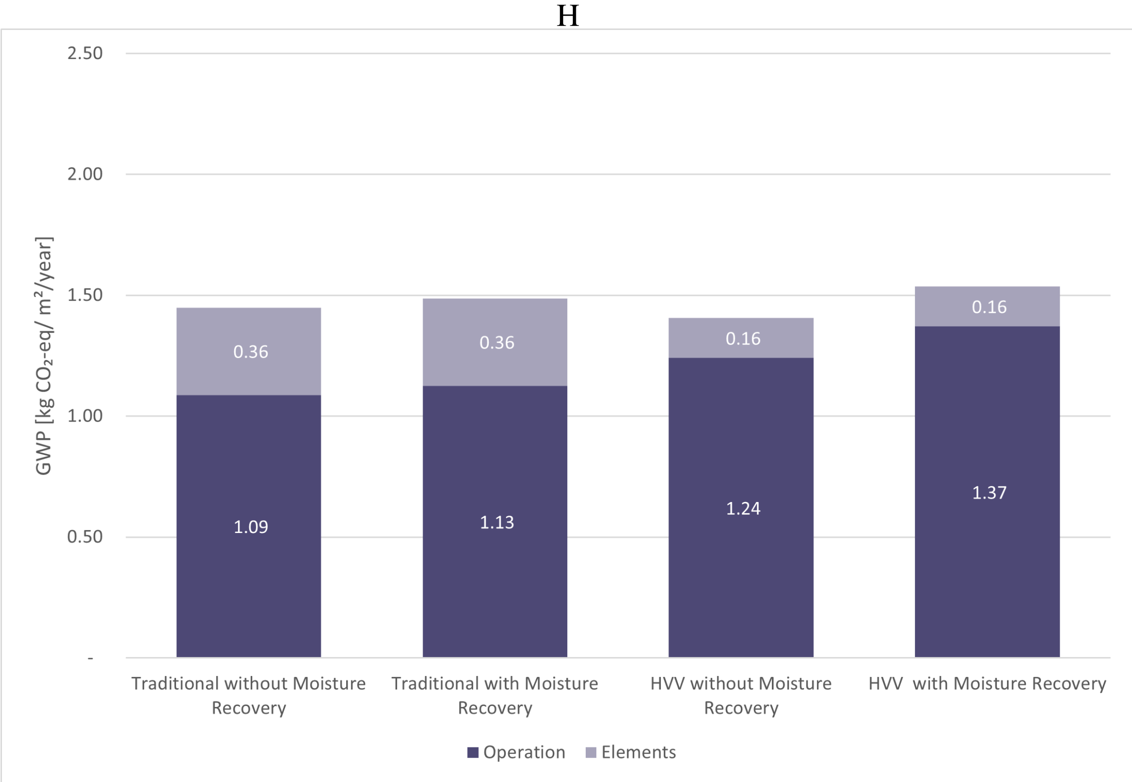


Figure 11.3: LCA results for elderly couple for set point of 20°C

11.2.4 Elderly Couple with 22°C set point

In the scenario where an elderly couple occupies the building with a higher set point of 22°C, operational impacts increase across all system variations due to the higher set point temperature. Moisture recovery, when present, introduces slight variations in both operational and life cycle impacts. The "Air-Based without Moisture Recovery" option exhibits the lowest operational impact at 1.72 CO_2eq/m2 per year, indicating more efficient energy use in maintaining the higher set point. This system also demonstrates the lowest total impact. Moisture recovery, while beneficial for indoor air quality and comfort, has a noticeable impact on energy efficiency. The HVV with Moisture Recovery option shows a higher total impact due to the additional energy requirements associated with moisture recovery processes and lower heat recovery capabilities.

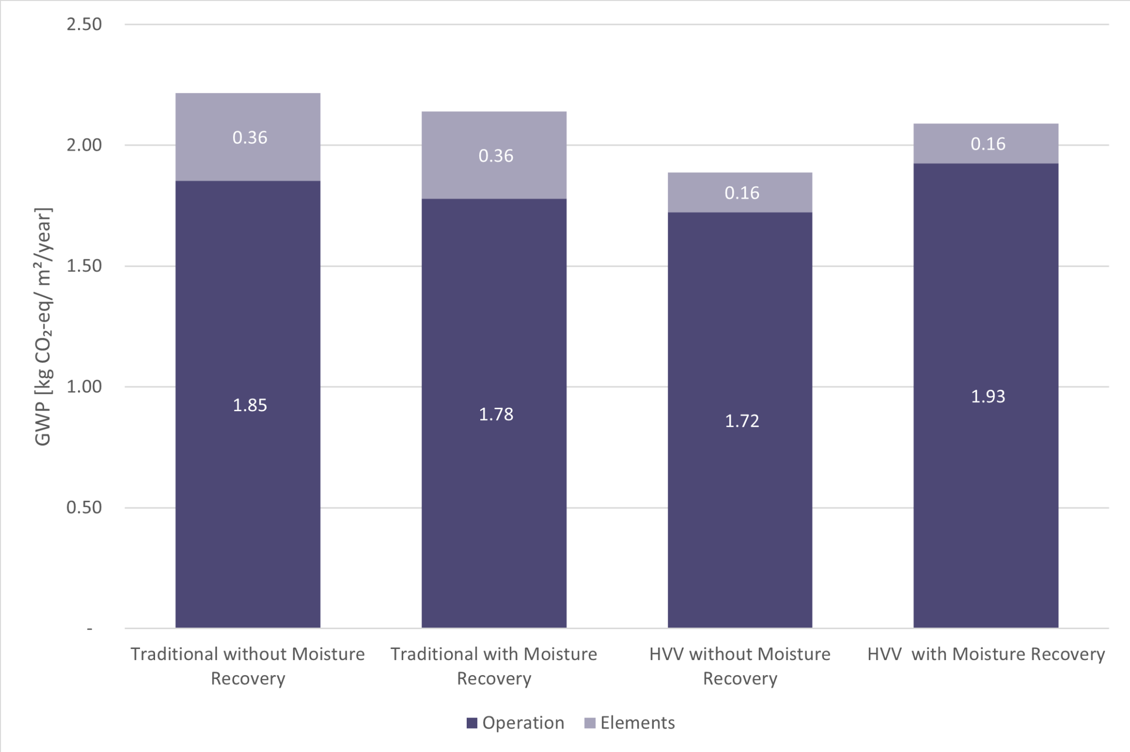


Figure 11.4: LCA results for elderly couple for set point of 22°C

11.2.5 Working Couple with 20°C set point

In the scenario where a working couple occupies the building with a set point of 20°C. The Traditional without Moisture Recovery option exhibits the lowest total impact and the lowest operational impact at 1.36 CO_2eq/m2 per year, indicating more efficient energy use in maintaining the set point of 20°C. It can be seen that HVV system demonstrates relatively more operational impact in both cases.

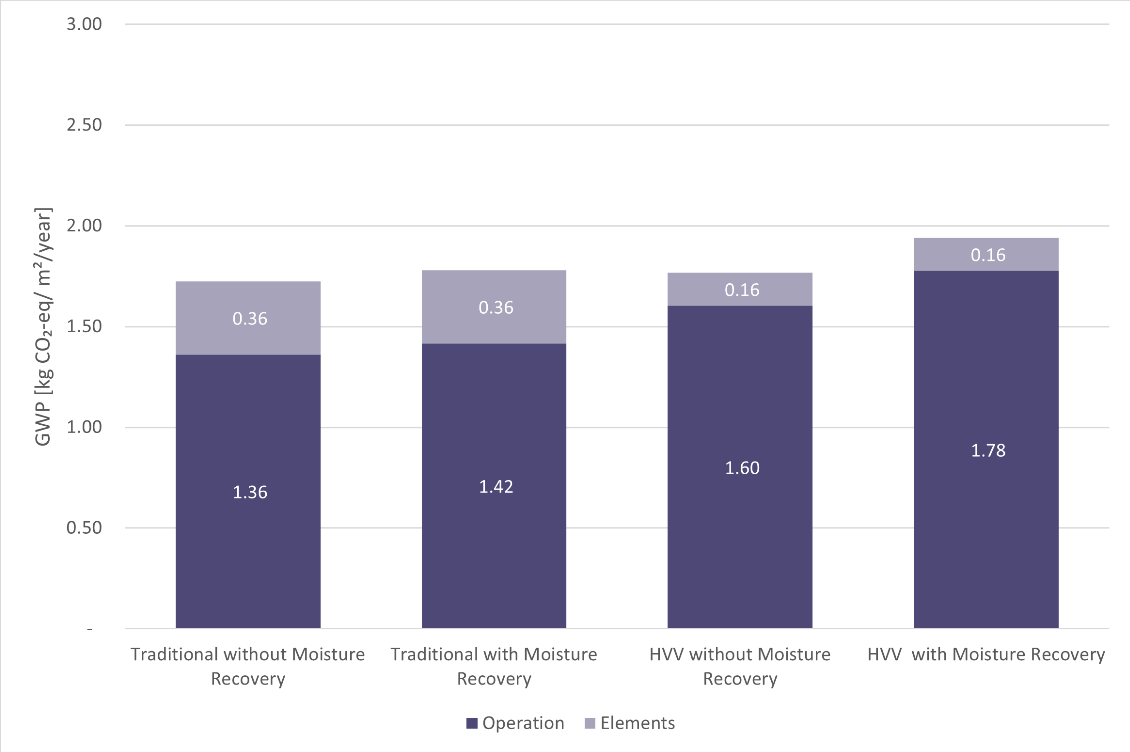


Figure 11.5: LCA results for working couple for set point of 20°C

11.2.6 Working Couple with 22°C set point

In the scenario where a working couple occupies the building with a set point of 22°C, operational impacts increase even more across all system variations due to the higher set point of 22°C. The figure shows that, HVV system without Moisture Recovery option exhibits the lowest total impact.

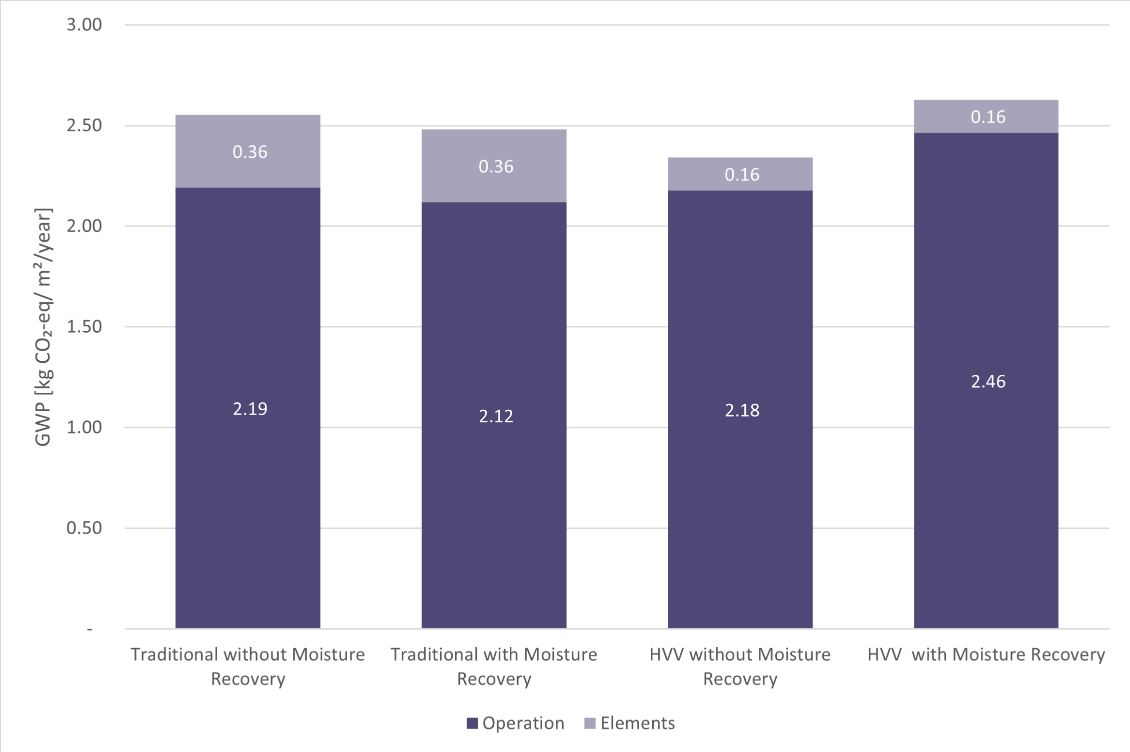
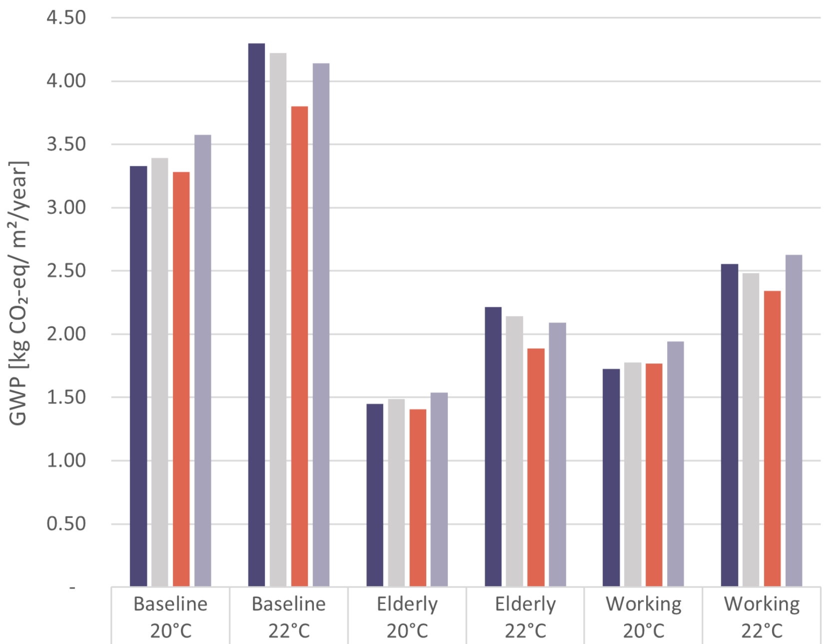


Figure 11.6: LCA results for working couple for set point of 22°C

11.3 Conclusion

The LCA analysis of two system and different variations across scenarios provides valuable insights into their environmental impacts, particularly concerning operational energy use and life cycle considerations. In general, when set point is set to 20°C all systems demonstrated relatively low operational impacts at this set point. However, when set point is set to 22°C operational impacts increased across all systems due to the higher set point. Scenario with HVV without moisture recovery proved to be more energy-efficient, exhibiting lower operational and total environmental impacts. One can note that in a traditional system, replacing the AHU with one without moisture recovery cause a slight difference in operational impact. However, the difference becomes more evident in scenarios involving HVV systems. While moisture recovery contributes to enhanced IAQ and comfort, its presence introduces additional energy demands. Also, it should be noted that ventilation unit without moisture recovery has higher heat recovery.

In general, scenario with HVV without Moisture Recovery option demonstrated higher energy efficiency across various scenarios, particularly at higher temperature set points.



	Baseline 20°C	Baseline 22°C	Elderly 20°C	Elderly 22°C	Working 20°C	Working 22°C
Traditional Without Moisture Recovery	3.33	4.30	1.45	2.22	1.72	2.55
Traditional With Moisture Recovery	3.39	4.22	1.49	2.14	1.78	2.48
HVV Without Moisture Recovery	3.28	3.8	1.41	1.89	1.77	2.34
HVV With Moisture Recovery	3.57	4.14	1.54	2.09	1.94	2.63

Figure 11.7: LCA Comparison between scenarios

Chapter 12

Discussion

The primary objective of this study was to investigate to what extent the choice of heat valve ventilation system compared to traditional heating and mechanical ventilation systems can help with reaching CO2 emissions as low as 2.5 kg CO_2 -eq/m^2 /year. The focus was on optimizing the choice of heating and ventilation system without influencing the thermal comfort and indoor air quality. The paper explored various scenarios involving different temperature set points, occupancy profiles, and the use of air handling units with and without moisture recovery with different heat recovery capabilities. The overarching goal was to minimize CO2 emissions while maintaining indoor environmental quality.

The life cycle analysis revealed that, in general, scenarios involving HVV systems without moisture and with higher heat recovery demonstrated higher energy efficiency across various conditions, particularly at higher temperature set points. Notably, higher heat recovery played a crucial role in the performance of HVV systems, especially at a set point of 22°C. In scenarios with lower set points or units incorporating moisture recovery and lower heat recovery, traditional systems outperformed HVV systems in terms of CO^2 emission. The results indicate that with increased heat recovery (0.92 for the traditional system and 0.9 for the HVV system), the CO2 emissions show a 0.5% to 3% improvement for a 20°C set point in the HVV system compared to the traditional system. Additionally, for a higher temperature set point of 22°C, the emissions are notably reduced, ranging from 11% to 15% when utilizing the HVV system as opposed to conventional heating and ventilation systems. Nevertheless, employing a unit with lower heat recovery (0.85) resulted in CO^2 emissions per year being 4-7% higher when utilizing the HVV system compared to traditional systems. However, when the set point was adjusted to 22°C, there was either no significant difference or, in some instances, the HVV system emitted 2.5% less CO_2 -eq/m^2 /year. The study demonstrates a correlation between higher heat recovery and CO^2 emissions. The data indicates that the HVV system performs better when equipped with an AHU unit featuring higher heat recovery, regardless of the set point. Nevertheless, the performance difference becomes more visible when the set point is higher. This analysis supports the theory that HVV systems require fewer materials for installation, and findings from life cycle analysis indicate that the CO^2 emission from elements are up to 50% lower compared to traditional heating and ventilation systems. In the context of our research, which specifically focuses on the heating season, the findings indicate that both systems maintain desired set points. The examination of moisture levels showed that in both systems, moisture levels remain generally low during colder months. Nevertheless, in the HVV system, particularly in March, if moisture recovery is not implemented, the relative moisture falls below the comfortable level of 25% for a long period of time.

The findings aligned with previous research indicating the impact of heat demand on the efficiency of HVV systems in buildings. It is demonstrated that when the building is occupied by elderly individuals, characterized by higher heat loads, the system demonstrates improved energy efficiency and reduced CO_2 -eq/m^2 /year. The results support the claims of *Polak, Joanna* [12] that HVV systems are more effective in terms of energy efficiency when employed in buildings with low heat demand. While earlier studies primarily assessed the performance of HVV systems at the room level, these results illustrate that the innovative air-based system is also more energy-efficient and can contribute to achieving lower CO^2 emissions under specific conditions. The paper's findings suggest that the performance of HVV systems is multifaceted, and factors such as heat recovery, temperature set points, and occupancy profiles must be considered. The LCA and simulation provide new insight into the relationship between these factors and the advantages of implementing HVV systems. These implications have practical relevance for decision-makers and stakeholders seeking to implement sustainable heating and ventilation systems in residential buildings.

Acknowledging the limitations of this study is crucial. Factors such as variations in building design or weather data could impact the findings. Furthermore, the investigation focused on a specific critical apartment, and applying the results to types of apartments may require additional investigation. However, the chosen apartment was critical in terms of heat losses. The paper's findings suggest that HVV systems should show similar or improved performance in the case of other apartments in the Green HUB House building. The reliability of LCA analysis was impacted by the limited EPD documentation available for HVV systems. The LCA conducted for the traditional system was more precise due to widely accessible data. However, for HVV systems, particularly the manifold component, data had to be estimated based on material take-off from the producer Therefore, more accurate LCA analysis for HVV systems should be compared with EPD documentation, which is currently unavailable.

Chapter 13

Conclusion

This research aimed to identify to what extend the choice of heat valve ventilation system compared to traditional heating and mechanical ventilation systems can help with reaching CO2 emissions as low as 2.5 kg CO_2 -eq/m^2 /year. The primary objective was to reduce CO^2 emissions and ensure a comfortable indoor environment. By testing both systems among different scenarios, this study established that when heat recovery was higher (0.9 and 0.92) HVV system produced up to 15% less CO_2 -eq/m^2 /year than traditional in case of 22°C set point temperature. However, in the case of lower heat recovery (0.85) traditional system was a more sustainable option when the set point was at 20°C. Adjusting the set point to 22°C showed either no significant difference or, in some cases, the HVV system emitted 2.5% less CO_2 -eq/m^2 /year. Simulations of various scenarios indicate that thermal comfort is maintained during the heating season in all cases. In terms of energy efficiency, HVV proves to be more effective than a traditional system when the temperature set point is higher. Additionally, CO^2 concentration is lower in the case of the HVV system. Regarding moisture levels, traditional systems appear to manage them more effectively. Nevertheless, in both scenarios, the moisture levels remain within the comfortable range. Generally, both systems can maintain a comfortable indoor environment under various conditions, including different set points and occupancy profiles. Based on the findings, it is recommended that future studies explore focus on periods outside the heating season. While this paper is focused on the heating season, the results reveal a significant number of recorded hours below 20°C outside this period. To improve thermal comfort, it is recommended to reduce airflow during these times. The HVV system, characterized by larger airflow, contributes to increased ventilation losses in during those months.

Based on life cycle analyses and simulations of the indoor environment, it can be concluded that the adoption of air heating systems in modern buildings can reduce CO^2 emission and maintain a comfortable indoor environment.

The scope of this paper is limited to a single apartment rather than the entire building. It's important to highlight that the analyzed apartment is critical and the performance of other apartments within the building is expected to be even better. As a result, achieving the goal of 2.5 kg CO_2 -eq/m^2 /year is promising.

Overall, choice of heat valve ventilation system over to traditional heating and mechanical ventilation system can help with reducing CO^2 emissions of 11% - 15% when a unit with higher heat recovery is applied in the system and the set point temperature is set to 22°C.

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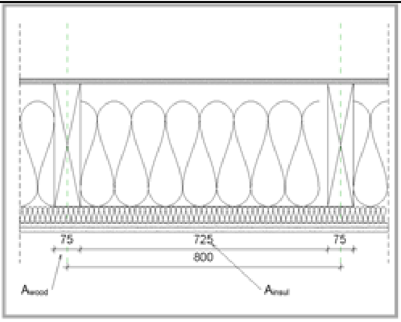
Appendix A

Appendix A

Appendix A includes calculations regarding U-Values, transmission, linear and ventilation losses for the analysed apartment.

Construction	Material layer	d [m]	l_{design} [W/mK]	R [m^2K/W]
	**Rsi**			0.10
	gypsum board, 2 layers	0.026	0.250	0.10
	battens w/ insulation	0.045	0.039	1.17
	rafters w/ insulation	0.30	0.040	7.45
	Ventilated airspace Rsi			0.10
			ΣR_{layer}	8.92
			U' [W/m^2K]	**0.112**

λ might be find in DS418 Table F.2 Design values for other building materials

λ calculations for rafters with		λ calculations for battens with	
Awood	75	Awood	45
λwood	0.12	λwood	0.12
Ainsul	725	Ainsul	555
λinsul	0.032	λinsul	0.032
Finalλ	0.04025	Finalλ	0.0386

$$\lambda' = \frac{A_{wood} \cdot \lambda_{wood} + A_{insul} \cdot \lambda_{insul}}{A_{wood} + A_{insul}}$$

	Cells to fullfill
	Cells calculated automaticlly
0.112	Uncorrected transmission coefficient
0.120	Final U-value with corrections

Correction for air-cracks in the insulation layer		
ΔU'' => Level 1 for cold roof		0.01
ΔUg=	0.008	
Final U-value after corrections		
U=	0.120	

Table A.1 – Correction for air-cracks in the insulation layer

Level	ΔU'' W/m²K	Description
0	0,00	No air-cracks across the insulation layer
1	0,01	Possibility for air-cracks across the insulation layer No air circulation on the warm side of the insulation layer
2	0,04	Possibility for air-cracks across the insulation layer Possibility for air circulation on the warm side of the insulation layer

Final calculations of the U-value

The resulting transmission coefficient U is achieved by adding the correction ΔU:

$$U = U' + \Delta U$$

Where

$$\Delta U = \Delta U_g + \Delta U_f + \Delta U_r$$

where

ΔU_g is a correction for air-cracks in the insulation layer

ΔU_f is a correction for ties and similar mechanical fixations

ΔU_r is a correction for precipitation on "upside down" roof

A.2 Correction for air-cracks in the insulation layer

The correction ΔU_g must be adjusted for the heat flow resistance of the insulation relatively to the total heat flow resistance of the construction:

$$\Delta U_g = \Delta U'' \left(\frac{R_i}{R_T}\right)$$

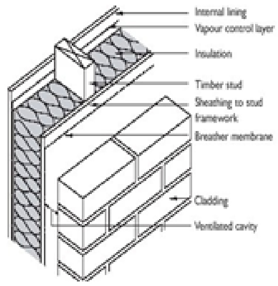
where

ΔU'' is the correction for air-cracks in the insulation layer. ΔU'' is found in table A.1.

R_i is the heat flow resistance of the insulation layer

R_T is the total heat flow resistance of the construction.

Figure A.1: U-value Calculation of Roof Construction

Construction	Material layer	d [m]	l_{design} [W/mK]	R [m^2K/W]
	Rsi			0.13
	gypsum board	0.016	0.190	0.08
	vapour control layer			
	den studs 600 c/c w/insul	0.250	0.000	0.00
	playwood	0.018	0.115	0.16
				0.00
				0.00
	Ventilated airspace Rsi			0.13
			ΣR_{layer}	0.50
			U' [W/m^2K]	1.999

λ might be find in DS418 Table F.2 Design values for other building materials

λ calculations for rafters with		λ calculations for battens with			
					Cells to fullfill
					Cells calculated automaticlly
				0.156	Uncorrected transmission coefficient
				0.156	Final U-value with corrections

$$\lambda' = \frac{A_{wood} \cdot \lambda_{wood} + A_{insul} \cdot \lambda_{insul}}{A_{wood} + A_{insul}}$$

Awood	70	Awood	45
λwood	0.12	λwood	0.12
Ainsul	530	Ainsul	555
λinsul	0.032	λinsul	0.032
Finalλ	0.042267	Finalλ	0.0386

ΔU" => Level 1 for cold roof	0
ΔU_g=	0.000
Final U-value after corrections	
U=	0.000
U=	0.156

Table A.1 – Correction for air-cracks in the insulation layer

Level	ΔU" W/m^2K	Description
0	0,00	No air-cracks across the insulation layer
1	0,01	Possibility for air-cracks across the insulation layer No air circulation on the warm side of the insulation layer
2	0,04	Possibility for air-cracks across the insulation layer Possibility for air circulation on the warm side of the insulation layer

Final calculations of the U-value

The resulting transmission coefficient U is achieved by adding the correction ΔU:

$$U = U' + \Delta U$$

Where

$$\Delta U = \Delta U_g + \Delta U_f + \Delta U_r$$

where

ΔU_g is a correction for air-cracks in the insulation layer
ΔU_f is a correction for ties and similar mechanical fixations
ΔU_r is a correction for precipitation on "upside down" roof

A.2 Correction for air-cracks in the insulation layer

The correction ΔU_g must be adjusted for the heat flow resistance of the insulation relatively to the total heat flow resistance of the construction:

$$\Delta U_g = \Delta U'' \left(\frac{R_i}{R_T}\right)$$

where

ΔU" is the correction for air-cracks in the insulation layer. ΔU" is found in table A.1.
R_i is the heat flow resistance of the insulation layer
R_T is the total heat flow resistance of the construction.

Figure A.2: U-value Calculation of Wall Construction

Living room/kitchen			
Transmission area			
	Height/Width	Length/Width	Area
	[m]	[m]	[m]
external wall	3.2	13.81	44.192
roof	4.055	9.755	43.6
roof entrance	3.9	2.185	7.79
balcony window			4.96
window x2	1.6	1.5	4.8
			9.76
Line loss			
foundation		0	
balcony	2.6	2.4	10
window	1.6	1.5	6.2
roof			13.81

Bedroom			
Transmission area			
	Height/Width	Length/Width	Area
	[m]	[m]	[m]
external wall	3.2	3.9	12.48
roof	3.9	4.011	17.65
window			4.96
line loss			
foundation		0	
window	2.6	2.4	10
roof			3.9

Bathroom			
Transmission area			
	Height/Width	Length/Width	Area
	[m]	[m]	[m]
external wall	0	0	0
roof	3.15	2.759	9.1
window			0
line loss			
foundation		0	
window		0	
roof		0	

Figure A.3: Linear and Transmission Losses Calculation

	Living room/kitchen				
$\Phi_n = \Phi_{transmission} + \Phi_{ventilation} + \Phi_{line\ loss}$					
		672.30			
	trans Loss	608.60			
floor	A	0			
	U	0.096		ti	to
	ΔT	10		20	10
external wall	A	34.432			
	U	0.16		ti	to
	ΔT	32		20	-12
window	A	9.76			
	U	0.79		ti	to
	ΔT	32		20	-12
roof	A	51.39			
	U	0.11		ti	to
	ΔT	32		20	-12
	vent. Loss	63.67			
	ρ	1.204			
	c	1005			
	q	94.716		ti	to
		32		20	-12
	line loss	0			
foundat	ψf	0.13			
	lf	0		ti	to
	ΔT	42		30	-12
windows	ψf	0			
	lf	16.2		ti	to
	ΔT	32		20	-12
roof	ψf	0			
	lf	13.81		ti	to
	ΔT	32		20	-12

Figure A.4: Heat Loss calculation from the Kitchen and Living area

	Bedroom				
	$\Phi_n = \Phi_{transmission} + \Phi_{ventilation} + \Phi_{line\ loss}$				
		250.05			
	trans Loss	231.60			
floor	A	0			
	U	0.096		ti	to
	ΔT	10		20	10
external wall	A	7.52			
	U	0.16		ti	to
	ΔT	32		20	-12
window	A	4.96			
	U	0.79		ti	to
	ΔT	32		20	-12
roof	A	17.65			
	U	0.112067		ti	to
	ΔT	32		20	-12
	vent. Loss	18.45			
	ρ	1.204			
	c	1005			
	q	18.45		ti	to
		32		20	-12
	line loss	0			
	ψf	0.13			
	lf	0		ti	to
foundat	ΔT	42		30	-12
	ψf	0			
	lf	10		ti	to
windows	ΔT	32		20	-12
	ψf	0			
	lf	3.9		ti	to
roof	ΔT	32		20	-12

Figure A.5: Heat Loss calculation from the Bedroom

	Batroom				
	$\Phi_n = \Phi_{transmission} + \Phi_{ventilation} + \Phi_{line\ loss}$				
		33.40			
	trans Loss	33.40			
floor	A	0			
	U	0.096		ti	to
	ΔT	10		20	10
external wall	A	0			
	U	0.16		ti	to
	ΔT	32		20	-12
window	A	0			
	U	0.79		ti	to
	ΔT	32		20	-12
roof	A	9.1			
	U	0.112067		ti	to
	ΔT	32		20	-12
	vent. Loss	0.00			
	ρ	1.204			
	c	1005			
	q	0		ti	to
		32		20	-12
	line loss	0			
foundat	ψf	0.13			
	lf	0		ti	to
	ΔT	42		30	-12
windows	ψf	0			
	lf	0		ti	to
	ΔT	32		20	-12
roof	ψf	0			
	lf	0		ti	to
	ΔT	32		20	-12

Figure A.6: Heat Loss calculation from the Bathroom

Appendix B

Appendix B

Appendix B contains calculations and data related to project input.

People								
Time	Week day				Weekend			
	[W]			[%]	[W]			[%]
	Bedroom	Livingroom	Per person		Bedroom	Livingroom	Per person	
1	70	0	35	31	70	0	35	31
2	70	0	35	31	70	0	35	31
3	70	0	35	31	70	0	35	31
4	70	0	35	31	70	0	35	31
5	70	0	35	31	70	0	35	31
6	70	0	35	31	70	0	35	31
7	70	0	35	31	70	0	35	31
8	0	218	109	95	0	109	55	47
9	0	174	87	76	0	109	55	47
10	0	87	44	38	0	55	27	24
11	0	87	44	38	0	55	27	24
12	0	221	110	96	72	0	36	31
13	0	276	138	120	0	69	34	30
14	0	308	154	134	0	69	34	30
15	0	232	116	101	0	230	115	100
16	0	218	109	95	0	212	106	92
17	0	218	109	95	0	123	62	54
18	0	218	109	95	0	109	55	47
19	0	218	109	95	0	109	55	47
20	101	0	51	44	101	0	51	44
21	101	0	51	44	101	0	51	44
22	70	0	35	31	70	0	35	31
23	70	0	35	31	70	0	35	31
24	70	0	35	31	70	0	35	31
	902	2475.6	1688.8		974	1246.5	1110.25	

Figure B.1: Internal heat loads from people for elderly couple

Equipment								
Time	Week day				Weekend			
	[W]			[%]	[W]			[%]
1	0	167	167	12	0	167	167	12
2	0	167	167	12	0	167	167	12
3	0	167	167	12	0	167	167	12
4	0	167	167	12	0	167	167	12
5	0	167	167	12	0	167	167	12
6	0	167	167	12	0	167	167	12
7	0	167	167	12	0	167	167	12
8	0	311	311	23	0	337	337	25
9	0	323	323	24	0	337	337	25
10	0	255	255	19	0	252	252	19
11	0	255	255	19	0	252	252	19
12	0	769	769	58	80	167	247	18
13	0	1125	1125	84	0	252	252	19
14	0	321	321	24	0	252	252	19
15	0	321	321	24	0	349	349	26
16	0	321	321	24	0	337	337	25
17	0	299	299	22	0	337	337	25
18	0	337	337	25	0	337	337	25
19	0	337	337	25	0	337	337	25
20	170	167	337	25	170	1167	1337	100
21	170	167	337	25	170	1167	1337	100
22	0	167	167	12	0	167	167	12
23	0	167	167	12	0	167	167	12
24	0	167	167	12	0	167	167	12
	340	6970	7310		420	7542.5	7962.5	

Figure B.2: Internal heat loads from equipment for elderly couple

People								
Time	Week day				Weekend			
	[W]			[%]	[W]			[%]
	Bedroom	Livingroom	Per person		Bedroom	Livingroom	Per person	
1	70	0	35	25	70	0	35	25
2	70	0	35	25	70	0	35	25
3	70	0	35	25	70	0	35	25
4	70	0	35	25	70	0	35	25
5	70	0	35	25	70	0	35	25
6	70	0	35	25	70	0	35	25
7	0	55	27	19	70	0	35	25
8	0	0	0	0	35	55	45	32
9	0	0	0	0	0	109	55	38
10	0	0	0	0	0	109	55	38
11	0	0	0	0	0	109	55	38
12	0	0	0	0	72	212	142	100
13	0	0	0	0	0	227	114	80
14	0	0	0	0	0	227	114	80
15	0	0	0	0	0	72	36	25
16	0	0	0	0	0	55	27	19
17	0	135	68	48	0	55	27	19
18	0	135	68	48	0	55	27	19
19	0	109	55	38	0	55	27	19
20	102.6	0	51	36	50.5	0	25	18
21	102.6	0	51	36	50.5	0	25	18
22	70	0	35	25	35	0	18	12
23	70	0	35	25	35	0	18	12
24	70	0	35	25	35	0	18	12
	835.2	434.3	634.75	447.007	803	1337.5	1070.25	753.6972

Figure B.3: Internal heat loads from people for working couple

Equipment								
Time	Week day				Weekend			
	[W]			[%]	[W]			[%]
	Bedroom	Livingroor	Per person		Bedroom	Livingroor	Per person	
1	0	167	167	14	0	167	167	14
2	0	167	167	14	0	167	167	14
3	0	167	167	14	0	167	167	14
4	0	167	167	14	0	167	167	14
5	0	167	167	14	0	167	167	14
6	0	167	167	14	0	167	167	14
7	0	167	167	14	0	167	167	14
8	0	167	167	14	0	252	252	22
9	0	167	167	14	0	352	352	30
10	0	167	167	14	0	352	352	30
11	0	167	167	14	0	352	352	30
12	0	167	167	14	80	173	253	22
13	0	167	167	14	0	898	898	77
14	0	167	167	14	0	173	173	15
15	0	167	167	14	0	167	167	14
16	0	167	167	14	0	1167	1167	100
17	0	189	189	16	0	1167	1167	100
18	0	883	883	76	0	667	667	57
19	0	303	303	26	0	252	252	22
20	100	167	267	23	85	167	252	22
21	40	167	207	18	0	167	167	14
22	0	167	167	14	0	167	167	14
23	0	167	167	14	0	167	167	14
24	0	167	167	14	0	167	167	14
	140	4874	5014		165	7968.75	8133.75	

Figure B.4: nternal heat loads from equipment for working couple

Bedroom														
	Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday	
	people	eqiupmer	people	eqiupmer	people	eqiupmer	people	eqiupmer	people	eqiupmer	people	eqiupmer	people	eqiupment
time	W		W		W		W		W		W		W	
1	140	0	140	0	140	0	140	0	140	0	140	0	140	0
2	140	0	140	0	140	0	140	0	140	0	140	0	140	0
3	140	0	140	0	140	0	140	0	140	0	140	0	140	0
4	140	0	140	0	140	0	140	0	140	0	140	0	140	0
5	140	0	140	0	140	0	140	0	140	0	140	0	140	0
6	140	0	140	0	140	0	140	0	140	0	140	0	140	0
7	140	0	140	0	140	0	140	0	140	0	140	0	140	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	288	160	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	202	170	202	170	202	170	202	170	202	170	202	170	202	170
21	202	170	202	170	202	170	202	170	202	170	202	170	202	170
22	140	0	140	0	140	0	140	0	140	0	140	0	140	0
23	140	0	140	0	140	0	140	0	140	0	140	0	140	0
24	140	0	140	0	140	0	140	0	140	0	140	0	140	0

Figure B.5: Hourly schedule of internal heat loads from the bedroom for elderly couple

Living room/kitchen + bathroom														
time	Monday		Tuesday	Wednesday			Thursday		Friday		Saturday		Sunday	
	people	eqiupmer	people	eqiupmer	people	eqiupmer	people	eqiupmer	people	eqiupmer	people	eqiupmer	people	eqiupment
	W		W		W		W		W		W		W	
1	0	167	0	167	0	167	0	167	0	167	0	167	0	167
2	0	167	0	167	0	167	0	167	0	167	0	167	0	167
3	0	167	0	167	0	167	0	167	0	167	0	167	0	167
4	0	167	0	167	0	167	0	167	0	167	0	167	0	167
5	0	167	0	167	0	167	0	167	0	167	0	167	0	167
6	0	167	0	167	0	167	0	167	0	167	0	167	0	167
7	0	167	0	167	0	167	0	167	0	167	0	167	0	167
8	218	267	218	277	218	337	218	337	218	337	218	337	218	337
9	218	437	0	167	218	337	218	337	218	337	218	337	218	337
10	218	437	0	167	0	167	0	167	218	337	0	167	218	337
11	218	437	0	167	0	167	0	167	218	337	0	167	218	337
12	278	1617	274	277	0	167	274	167	278	1617	0	167	0	167
13	278	437	274	1617	278	1617	274	1617	278	337	274	337	0	167
14	288	437	342	277	278	277	342	277	288	337	274	337	0	167
15	218	437	218	277	288	277	218	277	218	337	630	362	288	337
16	218	437	218	277	218	277	218	277	218	337	630	337	218	337
17	218	437	218	277	218	277	218	167	218	337	274	337	218	337
18	218	337	218	337	218	337	218	337	218	337	218	337	218	337
19	218	337	218	337	218	337	218	337	218	337	218	337	218	337
20	0	167	0	167	0	167	0	167	0	167	0	2167	0	167
21	0	167	0	167	0	167	0	167	0	167	0	2167	0	167
22	0	167	0	167	0	167	0	167	0	167	0	167	0	167
23	0	167	0	167	0	167	0	167	0	167	0	167	0	167
24	0	167	0	167	0	167	0	167	0	167	0	167	0	167

Figure B.6: Hourly schedule of internal heat loads from the Kitchen and Living area for elderly couple

Bedroom														
	Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday	
	people	eqiupmer	people	eqiupmer	people	eqiupmer	people	eqiupmer	people	eqiupmer	people	eqiupmer	people	eqiupment
time	W		W		W		W		W		W		W	
1	140	0	140	0	140	0	140	0	140	0	140	0	140	0
2	140	0	140	0	140	0	140	0	140	0	140	0	140	0
3	140	0	140	0	140	0	140	0	140	0	140	0	140	0
4	140	0	140	0	140	0	140	0	140	0	140	0	140	0
5	140	0	140	0	140	0	140	0	140	0	140	0	140	0
6	140	0	140	0	140	0	140	0	140	0	140	0	140	0
7	0	0	0	0	0	0	0	0	0	0	140	0	140	0
8	0	0	0	0	0	0	0	0	0	0	0	0	140	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	288	160	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	218	100	202	100	202	100	202	100	202	100	0	0	202	170
21	218	100	202	0	202	0	202	100	202	0	0	0	202	0
22	140	0	140	0	140	0	140	0	140	0	0	0	140	0
23	140	0	140	0	140	0	140	0	140	0	0	0	140	0
24	140	0	140	0	140	0	140	0	140	0	0	0	140	0

Figure B.7: Hourly schedule of internal heat loads from the bedroom for working couple

Living room/kitchen + bathroom														
time	Monday		Tuesday	Wednesday			Thursday		Friday		Saturday		Sunday	
	people	eqiupmer	people	eqiupmer	people	eqiupmer	people	eqiupmer	people	eqiupmer	people	eqiupmer	people	eqiupment
	W		W		W		W		W		W		W	
1	0	167	0	167	0	167	0	167	0	167	0	167	0	167
2	0	167	0	167	0	167	0	167	0	167	0	167	0	167
3	0	167	0	167	0	167	0	167	0	167	0	167	0	167
4	0	167	0	167	0	167	0	167	0	167	0	167	0	167
5	0	167	0	167	0	167	0	167	0	167	0	167	0	167
6	0	167	0	167	0	167	0	167	0	167	0	167	0	167
7	109	167	109	167	109	167	109	167	109	167	0	167	0	167
8	0	167	0	167	0	167	0	167	0	167	218	337	0	167
9	0	167	0	167	0	167	0	167	0	167	218	537	218	167
10	0	167	0	167	0	167	0	167	0	167	218	537	218	167
11	0	167	0	167	0	167	0	167	0	167	218	537	218	167
12	0	167	0	167	0	167	0	167	0	167	630	179	218	167
13	0	167	0	167	0	167	0	167	0	167	630	179	278	1617
14	0	167	0	167	0	167	0	167	0	167	630	179	278	167
15	0	167	0	167	0	167	0	167	0	167	0	167	288	167
16	0	167	0	167	0	167	0	167	0	167	0	167	218	2167
17	350	167	218	277	218	167	350	167	218	167	0	167	218	2167
18	350	1787	218	337	218	337	350	1787	218	167	0	167	218	1167
19	218	337	218	337	218	337	218	337	218	167	0	167	218	337
20	0	167	0	167	0	167	0	167	0	167	0	167	0	167
21	0	167	0	167	0	167	0	167	0	167	0	167	0	167
22	0	167	0	167	0	167	0	167	0	167	0	167	0	167
23	0	167	0	167	0	167	0	167	0	167	0	167	0	167
24	0	167	0	167	0	167	0	167	0	167	0	167	0	167

Figure B.8: Hourly schedule of internal heat loads from the Kitchen and Living area for working couple

Activity	Metabolic Rate		
		Man	Woman
	[W/m2]	[W]	
sleeping	40	76	64
seating	60	114	96
reading	55	104.5	88
typing	65	123.5	104
cooking	100	190	160
cleaning	180	342	288

Heat load source	Amount	[W]
TV	1	170
Laptop	1	100
Vacume cleaner	1	50
	1	7
Speaker System	2	110
Cooktop	1	1450
Washingmachine	1	2000
Fridge	1	167

Figure B.9: Heat loads from for various activities and equipment used in the calculation

Time	Mon	Tue	Wed	Thu	Fri	Sat	Sun				Time	Week		Weekend	
[kg/h]															
1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		1	0.09	60	0.091	60
2	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		2	0.09	60	0.091	60
3	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		3	0.09	60	0.091	60
4	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		4	0.09	60	0.091	60
5	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		5	0.09	60	0.091	60
6	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		6	0.09	60	0.091	60
7	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		7	0.09	60	0.091	60
8	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		8	0.09	60	0.091	60
9	0.09	0.01	0.09	0.09	0.09	0.01	0.09	0.07	74.06		9	0.07	49	0.049	33
10	0.09	0.01	0.01	0.01	0.09	0.01	0.09	0.04	48.11		10	0.04	27	0.049	33
11	0.09	0.01	0.01	0.01	0.09	0.01	0.09	0.04	48.11		11	0.04	27	0.049	33
12	0.18	0.09	0.09	0.18	0.09	0.01	0.01	0.09	102.96		12	0.13	84	0.008	5
13	0.11	0.18	0.18	0.11	0.18	0.09	0.01	0.12	135.11		13	0.15	100	0.049	33
14	0.09	0.11	0.11	0.09	0.09	0.09	0.01	0.08	91.76		14	0.10	64	0.049	33
15	0.09	0.09	0.09	0.09	0.09	0.13	0.09	0.10	105.78		15	0.09	60	0.109	72
16	0.09	0.09	0.09	0.09	0.09	0.13	0.09	0.10	105.78		16	0.09	60	0.109	72
17	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		17	0.09	60	0.091	60
18	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		18	0.09	60	0.091	60
19	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	122.99		19	0.11	74	0.111	74
20	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		20	0.09	60	0.091	60
21	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		21	0.09	60	0.091	60
22	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		22	0.09	60	0.091	60
23	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		23	0.09	60	0.091	60
24	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		24	0.09	60	0.091	60

Figure B.10: Moisture production by elderly couple

Time	Mon	Tue	Wed	Thu	Fri	Sat	Sun				Time	Week		Weekend	
[kg/h]															
1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		1	0.09	71	0.09	71
2	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		2	0.09	71	0.09	71
3	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		3	0.09	71	0.09	71
4	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		4	0.09	71	0.09	71
5	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		5	0.09	71	0.09	71
6	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		6	0.09	71	0.09	71
7	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		7	0.09	71	0.09	71
8	0.01	0.01	0.01	0.01	0.01	0.09	0.01	0.02	22.17		8	0.01	7	0.05	39
9	0.01	0.01	0.01	0.01	0.01	0.09	0.09	0.03	35.14		9	0.01	7	0.09	71
10	0.01	0.01	0.01	0.01	0.01	0.09	0.09	0.03	35.14		10	0.01	7	0.09	71
11	0.01	0.01	0.01	0.01	0.01	0.09	0.09	0.03	35.14		11	0.01	7	0.09	71
12	0.01	0.01	0.01	0.01	0.01	0.13	0.09	0.04	40.92		12	0.01	7	0.11	86
13	0.01	0.01	0.01	0.01	0.01	0.13	0.09	0.04	40.92		13	0.01	7	0.11	86
14	0.01	0.01	0.01	0.01	0.01	0.14	0.09	0.04	42.56		14	0.01	7	0.11	90
15	0.01	0.01	0.01	0.01	0.01	0.01	0.09	0.02	22.17		15	0.01	7	0.05	39
16	0.01	0.01	0.01	0.01	0.01	0.01	0.09	0.02	22.17		16	0.01	7	0.05	39
17	0.18	0.09	0.09	0.18	0.09	0.01	0.13	0.11	121.68		17	0.13	100	0.07	53
18	0.18	0.09	0.09	0.18	0.09	0.01	0.10	0.11	117.57		18	0.13	100	0.05	43
19	0.10	0.10	0.10	0.10	0.10	0.09	0.10	0.10	109.85		19	0.10	79	0.10	75
20	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		20	0.09	71	0.09	71
21	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		21	0.09	71	0.09	71
22	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		22	0.09	71	0.09	71
23	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		23	0.09	71	0.09	71
24	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	100.00		24	0.09	71	0.09	71

Figure B.11: Moisture production by working couple

Source	Moisture load			
	kg/day (4)	kg/day (1)	kg/h	%
Occupants	3.95	0.99	0.04	20.28
Cooking	2.20	2.20	0.09	45.17
Washing cloths	0.50	0.25	0.01	5.13
Washing floors surfaces	0.88	0.88	0.04	18.07
Washing dishes	0.45	0.36	0.02	7.39
Drying cloths	1.25	0.63	0.03	12.83
Bathing washing	1.00	0.25	0.01	5.13
Plant	0.20	0.20	0.01	4.11

Figure B.12: Moisture production data from occupants and various sources

Appendix C

Appendix C

This Appendix contain calculations of designing heating and ventilation systems.

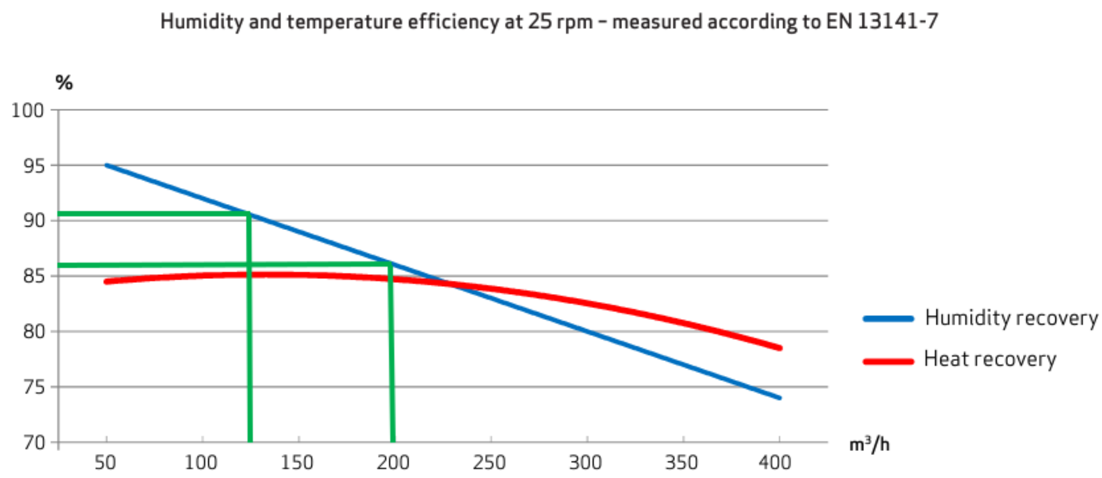


Figure C.1: Ventilation unit ECO360R temperature and moisture efficiency

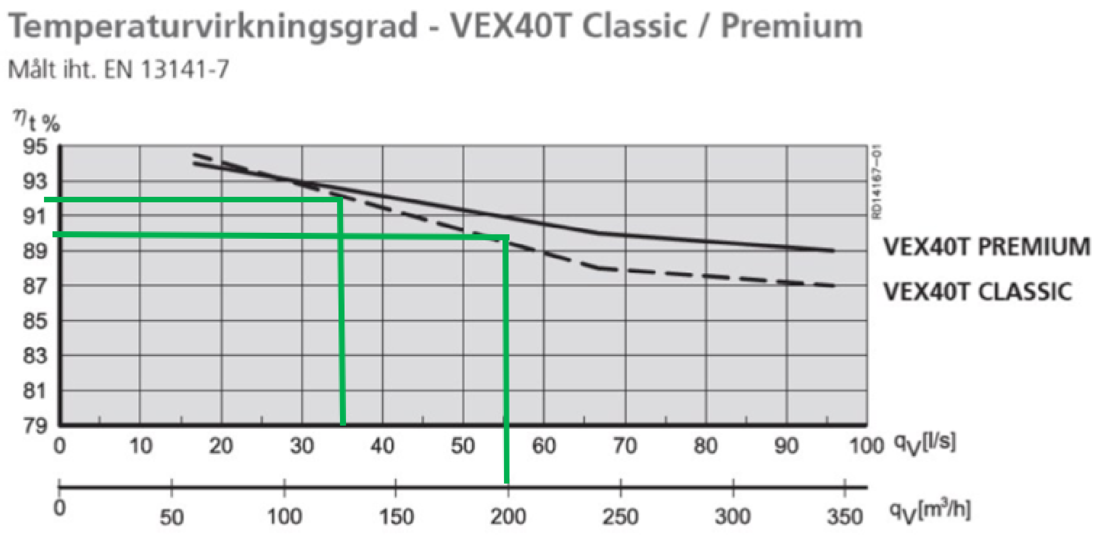


Figure C.2: Ventilation unit VEX40T temperature efficiency

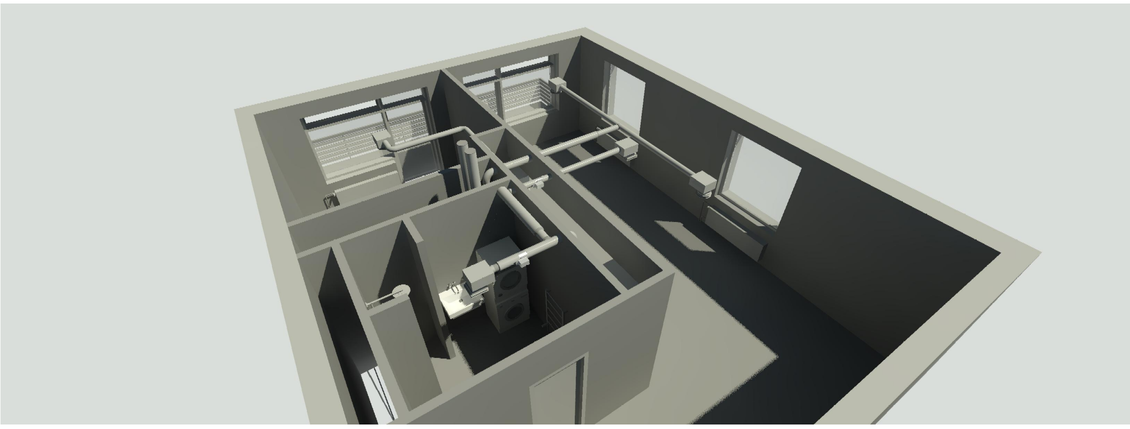


Figure C.3: Render of Traditional Systems

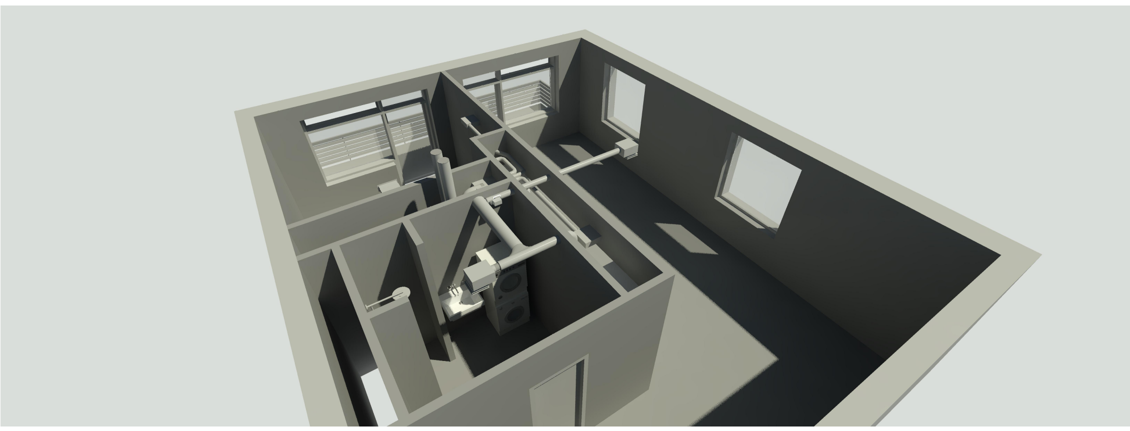


Figure C.4: Render of HVV System

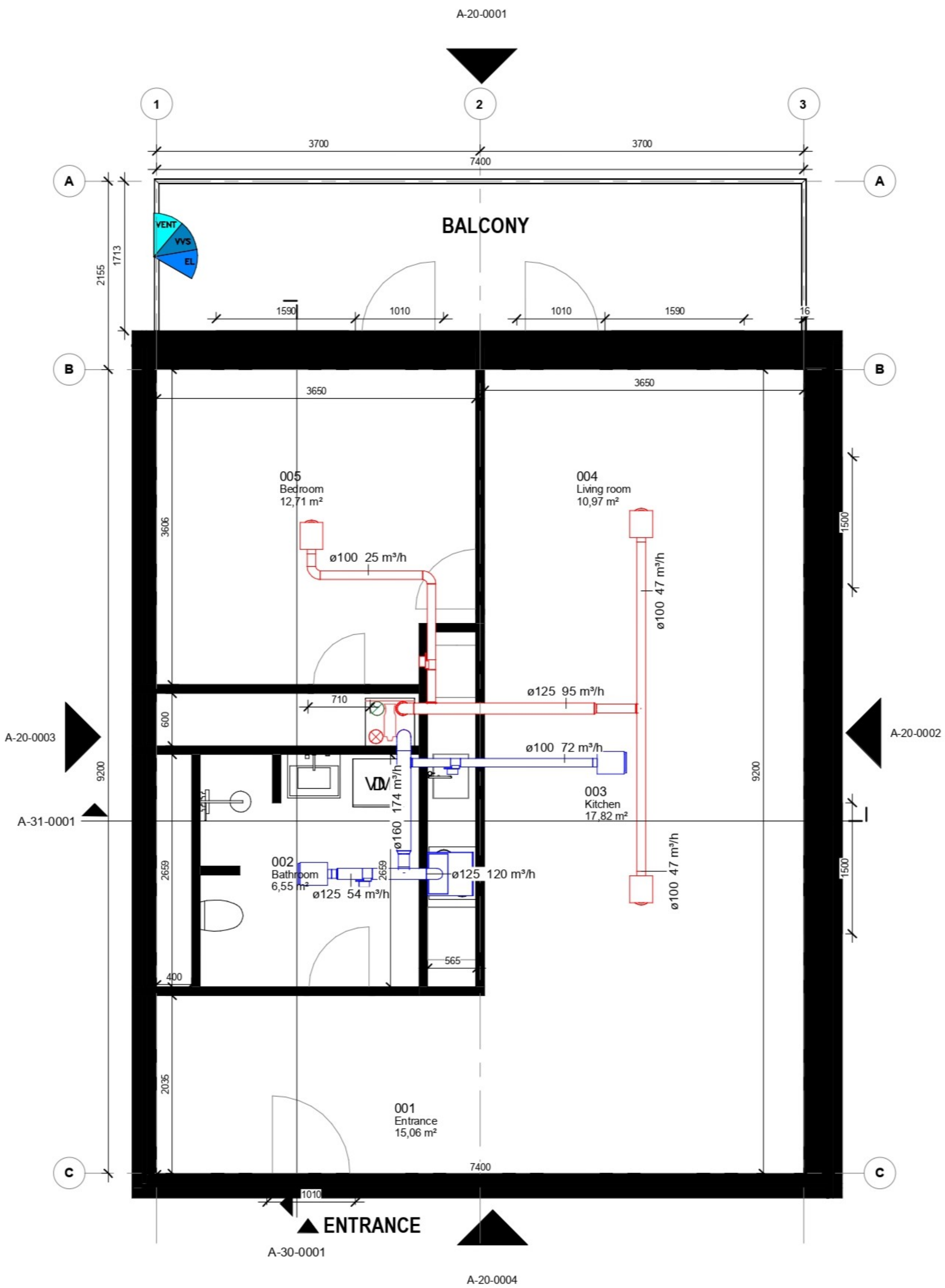


Figure C.5: Plan of traditional Ventilation System

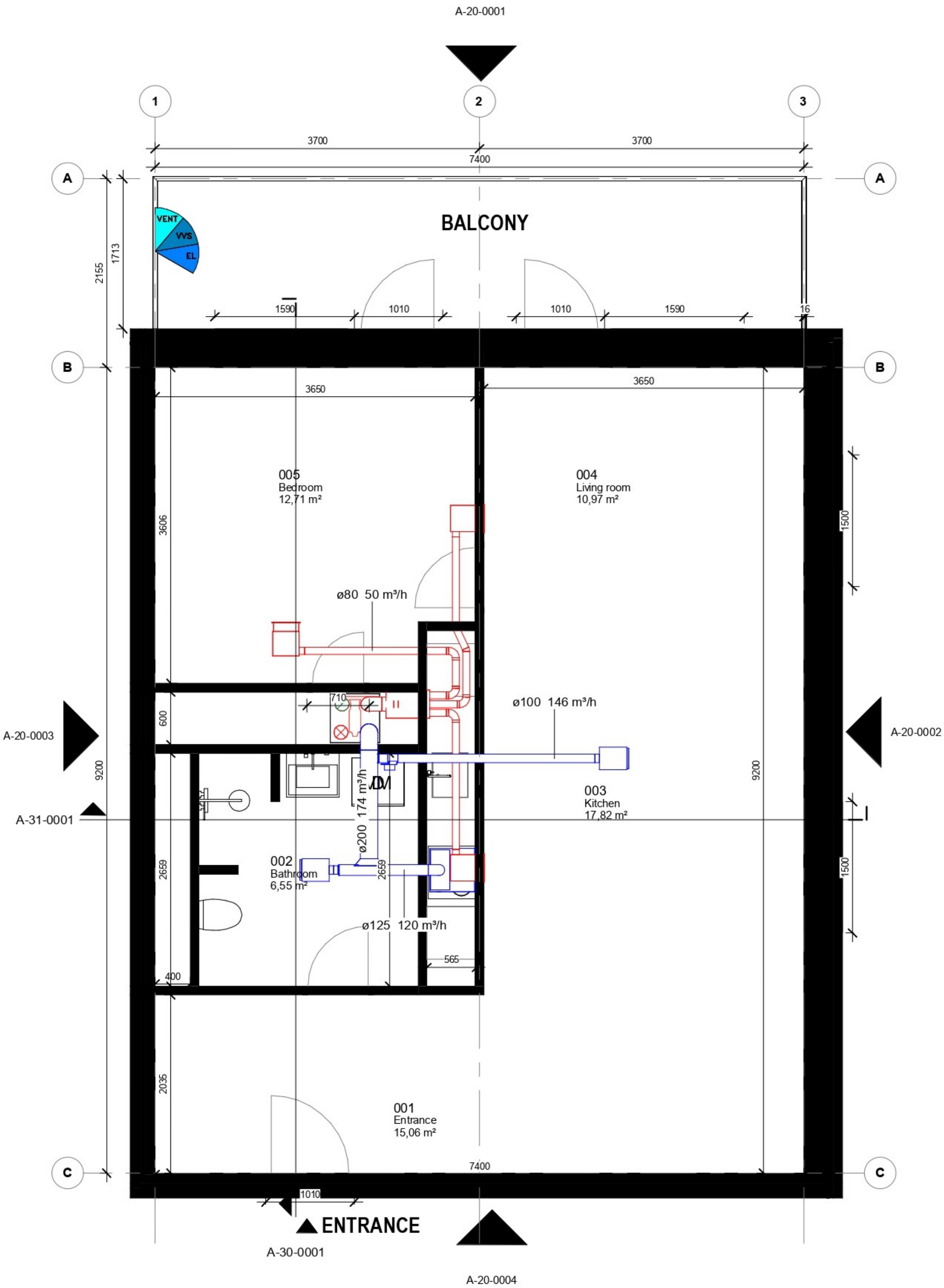


Figure C.6: Plan of HVV System

Entrance/ Kitchen / Living area						
Construction:	Area: [m²]	U-value: [W/m²K]	Temp. ins.: [°C]	Temp out.: [°C]	Δtemp [°C]	Trans. loss (ΦT) [W]
Exterior Wall	34.4	0.15	20	-12	32	165.12
Floor	0	0	20	10	10	0
Roof	51.24	0.12	20	-12	32	196.7616
Windows	9.76	0.79	20	-12	32	246.7328
Doors	-	-	-	-		

Bathroom						
Construction:	Area: [m²]	U-value: [W/m²K]	Temp. ins.: [°C]	Temp out.: [°C]	Δtemp [°C]	Trans. loss (ΦT) [W]
Exterior Wall	0	0	20	-12	32	0
Floor	0	0.096	20	10	10	0
Roof	8.7	0.12	20	-12	32	33.408
Windows	0	0.79	20	-12	32	0
Doors	-	-	-	-		

Bedroom						
Construction:	Area: [m²]	U-value: [W/m²K]	Temp. ins.: [°C]	Temp out.: [°C]	Δtemp [°C]	Trans. loss (ΦT) [W]
Exterior Wall	7.52	0.16	20	-12	32	38.5024
Floor	0	0.096	20	10	10	0
Roof	17.65	0.12	20	-12	32	67.776
Windows	4.96	0.79	20	-12	32	125.3888
Doors	-	-	-	-		

Foundation linear loss						
Room	Length [m]	Ψ-value: [W/mK]	Temp. ins.: [°C]	Temp out.: [°C]	Δtemp [°C]	Trans. loss (ΦT) [W]
Entrance/ Kitchen / Living area	0	0.13	20	-12	32	0
Bathroom	0	0.13	20	-12	32	0
Bedroom	0	0.13	20	-12	32	0

Window linear loss						
Room	Length [m]	Ψ-value: [W/mK]	Temp. ins.: [°C]	Temp out.: [°C]	Δtemp [°C]	Trans. loss (ΦT) [W]
Entrance/ Kitchen / Living area	16.2	0	20	-12	32	
Bathroom	0	0	20	-12	32	
Bedroom	10	0	20	-12	32	

Figure C.7: Heat loss calculations

Heating demand			
	Trans. heat loss (Φt)	nt. heat loss (Φ	Total heat loss (Φ)
	[W]	[W]	[W]
Entrance/ Kitchen / Living area	608.61	63.67	672.29
Bathroom	33.41	0.00	33.41
Bedroom	231.67	18.45	250.12

Figure C.8: Heating Demand

3rd floor					
			Living room/k	Bedrom	Bathroom
Designed	Heating demand (Φ)	[W]	672	250	33
	Amount of radiators	-	2	1	1
	Heating demand per radiator (Φ)	[W]	336	250	33
	Supply temp.	[°C]	40	40	40
	Return temp.	[°C]	25	25	25
	Indoor temp.	[°C]	20	20	20
	Log. Mean temp. dif. (Δtm)	[°C]	10.82021281	10.82021281	10.82021281
Standard	Model Name	-	2x C33 450 14	1x Purmo C22 450	1x Purmo FLO0505
	Height	[mm]	450	450	547
	Width	[mm]	1400	1400	500
	Standard heating output (Φo)	[W]	1146	830	110
	Supply temp.	[°C]	55	55	55
	Return temp.	[°C]	40	40	40
	Indoor temp.	[°C]	20	20	20
	Log. Mean temp. dif. (Δtmo)	[°C]	26.80410439	26.80410439	26.80410439
	Radiator factor	-	1.3	1.3	1.3
	Actual heating output	[W]	352.3947826	255.2248425	33.82497913

Figure C.9: Radiators calculations

Room	Area	Supply			Extract	
	[m2]	[l/s/m2]	[l/s]	[m3/h]	[l/s]	[m3/h]
Living room/kitchen	43.85	0.95	41.6575	149.967		
		0		0.041658	20	72
Bedroom	14	0.95	13.3	47.88		
Bathroom	6.55			0.0133	15	54
Total:	64.4		54.9575	197.902	35	**126**
		air flow in m3/s		0.054973		0.035

Figure C.10: Ventilation Calculations

Family and Type	System Classification	Size	Length
Round Duct: Lindab SR Standard			
ø100			
Round Duct: Lindab SR Standard	Return Air	ø100	1.511 m
Round Duct: Lindab SR Standard	Return Air	ø100	0.438 m
			1.949 m
Round Duct: Lindab SR Standard	Supply Air	ø100	0.145 m
Round Duct: Lindab SR Standard	Supply Air	ø100	0.171 m
Round Duct: Lindab SR Standard	Supply Air	ø100	0.867 m
Round Duct: Lindab SR Standard	Supply Air	ø100	3.767 m
Round Duct: Lindab SR Standard	Supply Air	ø100	0.446 m
Round Duct: Lindab SR Standard	Supply Air	ø100	0.367 m
			6.762 m
ø125			
Round Duct: Lindab SR Standard	Return Air	ø125	0.993 m
Round Duct: Lindab SR Standard	Return Air	ø125	0.617 m
Round Duct: Lindab SR Standard	Return Air	ø125	0.148 m
Round Duct: Lindab SR Standard	Return Air	ø125	0.285 m
			2.042 m
Round Duct: Lindab SR Standard	Supply Air	ø125	2.064 m
Round Duct: Lindab SR Standard	Supply Air	ø125	0.119 m
			2.183 m
ø160			
Round Duct: Lindab SR Standard	Exhaust Air	ø160	1.180 m
			1.180 m
Round Duct: Lindab SR Standard	Return Air	ø160	1.145 m
Round Duct: Lindab SR Standard	Return Air	ø160	0.347 m
			1.492 m
Round Duct: Lindab SR Standard	Supply Air	ø160	0.192 m
Round Duct: Lindab SR Standard	Supply Air	ø160	1.220 m
			1.412 m
Grand total			17.020 m

Figure C.11: Duct material take off - Traditional Ventilation System

Family and Type	System Type	Size	Length
Pipe Types: Steel pipe Fe-35			
15 mm			
Pipe Types: Steel pipe Fe-35	Heating return	15 mm	6.697 m
Pipe Types: Steel pipe Fe-35	Heating return	15 mm	0.079 m
Pipe Types: Steel pipe Fe-35	Heating return	15 mm	0.288 m
Pipe Types: Steel pipe Fe-35	Heating return	15 mm	1.980 m
Pipe Types: Steel pipe Fe-35	Heating return	15 mm	0.034 m
Pipe Types: Steel pipe Fe-35	Heating return	15 mm	0.288 m
Pipe Types: Steel pipe Fe-35	Heating return	15 mm	3.870 m
Pipe Types: Steel pipe Fe-35	Heating return	15 mm	0.049 m
Pipe Types: Steel pipe Fe-35	Heating return	15 mm	0.288 m
Pipe Types: Steel pipe Fe-35	Heating return	15 mm	0.516 m
Pipe Types: Steel pipe Fe-35	Heating return	15 mm	4.520 m
Pipe Types: Steel pipe Fe-35	Heating return	15 mm	0.816 m
Pipe Types: Steel pipe Fe-35	Heating return	15 mm	0.818 m
Pipe Types: Steel pipe Fe-35	Heating return	15 mm	0.628 m
Pipe Types: Steel pipe Fe-35	Heating return	15 mm	0.026 m
Pipe Types: Steel pipe Fe-35	Heating return	15 mm	3.653 m
			24.547 m
Pipe Types: Steel pipe Fe-35	Heating supply	15 mm	6.747 m
Pipe Types: Steel pipe Fe-35	Heating supply	15 mm	0.156 m
Pipe Types: Steel pipe Fe-35	Heating supply	15 mm	0.638 m
Pipe Types: Steel pipe Fe-35	Heating supply	15 mm	2.030 m
Pipe Types: Steel pipe Fe-35	Heating supply	15 mm	0.120 m
Pipe Types: Steel pipe Fe-35	Heating supply	15 mm	0.638 m
Pipe Types: Steel pipe Fe-35	Heating supply	15 mm	3.879 m
Pipe Types: Steel pipe Fe-35	Heating supply	15 mm	0.126 m
Pipe Types: Steel pipe Fe-35	Heating supply	15 mm	0.638 m
Pipe Types: Steel pipe Fe-35	Heating supply	15 mm	0.466 m
Pipe Types: Steel pipe Fe-35	Heating supply	15 mm	4.450 m
Pipe Types: Steel pipe Fe-35	Heating supply	15 mm	0.757 m
Pipe Types: Steel pipe Fe-35	Heating supply	15 mm	0.806 m
Pipe Types: Steel pipe Fe-35	Heating supply	15 mm	1.083 m
Pipe Types: Steel pipe Fe-35	Heating supply	15 mm	0.027 m
Pipe Types: Steel pipe Fe-35	Heating supply	15 mm	0.015 m
Pipe Types: Steel pipe Fe-35	Heating supply	15 mm	3.703 m
			26.276 m
Grand total			50.823 m

Figure C.12: Piping material take off - Traditional Heating Sysytem

Family and Type	System Classification	Size	Length
Round Duct: Lindab SR Standard			
ø80			
Round Duct: Lindab SR Standard	Supply Air	ø80	1.453 m
Round Duct: Lindab SR Standard	Supply Air	ø80	0.349 m
Round Duct: Lindab SR Standard	Supply Air	ø80	0.349 m
Round Duct: Lindab SR Standard	Supply Air	ø80	0.300 m
Round Duct: Lindab SR Standard	Supply Air	ø80	1.621 m
Round Duct: Lindab SR Standard	Supply Air	ø80	0.469 m
Round Duct: Lindab SR Standard	Supply Air	ø80	1.019 m
Round Duct: Lindab SR Standard	Supply Air	ø80	0.497 m
Round Duct: Lindab SR Standard	Supply Air	ø80	0.245 m
			6.301 m
ø100			
Round Duct: Lindab SR Standard	Return Air	ø100	2.251 m
Round Duct: Lindab SR Standard	Return Air	ø100	0.098 m
			2.349 m
ø125			
Round Duct: Lindab SR Standard	Return Air	ø125	0.993 m
Round Duct: Lindab SR Standard	Return Air	ø125	1.016 m
			2.009 m
ø160			
Round Duct: Lindab SR Standard	Exhaust Air	ø160	1.180 m
			1.180 m
Round Duct: Lindab SR Standard	Supply Air	ø160	0.115 m
Round Duct: Lindab SR Standard	Supply Air	ø160	1.220 m
Round Duct: Lindab SR Standard	Supply Air	ø160	0.134 m
			1.469 m
ø200			
Round Duct: Lindab SR Standard	Return Air	ø200	0.234 m
Round Duct: Lindab SR Standard	Return Air	ø200	1.241 m
			1.475 m
Grand total			14.782 m

Figure C.13: Duct material take off - HVV System

MagiCAD

Ductwork Pressure Drop Report

Project Information

Software version:	MagiCAD for Revit 2023	Calculation date:	10/01/2024 21:54
Project name:	Project Name	Project number:	Project Number
Project address:	Enter address in Project Information	Client name:	Owner
Project issue date:	Issue Date	Organization name:	
Organization description:		Author:	

Project Calculation Data

Systems:	- / - / - / -		
Total flow:	120 m³/h	Total pressure:	48.1 Pa

Calculation Input Values

Air Density:	1.20 kg/m3	Air Dynamic Viscosity:	0.00001813 Pa*s
Min. dp flow dampers:	20.0 Pa	Min. dp air devices:	20.0 Pa

Calculation Results / Supply

Location	Level	Node	Type	Series	Product	Size	L [m]	Insulation	qv set [m³/h]	qv [m³/h]	v [m/s]	dpt [Pa]	K factor	dp/L [Pa/m]	pt [Pa]	pst [Pa]	adj.	qv [%]	Warnings
	Level 1	6	AHE/AHU		VEX40T CLA				120	120					0				
	Level 1		DUCT	Lindab SR St		160	0.2		120	120	1.7	0.1		0.29	48.1	46.4			
	Level 1		REDUCER	Lindab SR St	RCFU_DK-*-*	160/125			120	120	1.7	0.2	0.037		48.0				
	Level 1		DUCT	Lindab SR St	SR-125	125	0.1		120	120	2.7	0.1		0.98	47.9	43.5			
	Level 1		BEND-90	Lindab SR St	BU-125-90	125			120	120	2.7	2.0	0.460		47.8				
	Level 1		DUCT	Lindab SR St	SR-125	125	0.1		120	120	2.7	0.1		0.98	45.7	41.3			
	Level 1		DUCT	Lindab SR St	SR-125	125	0.1		120	120	2.7				45.6				
	Level 1	3	TAP	Lindab SR St	PSU-125-100	125/100			25	25	0.9	4.5	1.022		45.6				
	Level 1		DUCT	Lindab SR St		100	0.4		25	25	0.9	0.1		0.18	41.1	40.6			
	Level 1	8	FLOWDAMP		REACT Pa 1	100			25	25	0.9	20.0			41.0		0.54	100	
	Level 1		DUCT	Lindab SR St	SR-100	100	0.9		25	25	0.9	0.2		0.18	21.0	20.5			
	Level 1		BEND-90	Lindab SR St	BU-100-90	100			25	25	0.9	0.3	0.655		20.9				
	Level 1		DUCT	Lindab SR St	SR-100	100	1.2		25	25	0.9	0.2		0.18	20.5	20.1			
	Level 1		BEND-90	Lindab SR St	BU-100-90	100			25	25	0.9	0.3	0.655		20.3				
	Level 1		DUCT	Lindab SR St	SR-100	100	0.1		25	25	0.9	0.0		0.18	20.0	19.6			
	Level 1	2	SUPPLY		PCA-100+MB	100			25	25	0.9	20.0			20.0		1.6	100	
	Level 1		DUCT	Lindab SR St	SR-125	125	1.8		95	95	2.1	1.1		0.64	30.8	28.1			
	Level 1		REDUCER	Lindab SR St	RCU-125-10	125/100			95	95	2.1	0.2	0.031		29.7				
	Level 1		DUCT	Lindab SR St	SR-100	100	0.4		95	95	3.4	0.9		1.91	29.5	22.7			
	Level 1	7	TAP	Lindab SR St	PSU-100-100	100/100			95	95	3.4				28.6				
	Level 1		DUCT	Lindab SR St	SR-100	100	0.1		95	95	3.4	7.6	1.133		28.6				
	Level 1		DUCT	Lindab SR St	SR-100	100	1.8		47	47	1.7	1.0		0.54	21.0	19.3			

1

Figure C.14: Pressure Loss of traditional ventilation system calculated by MagiCAD

MagiCAD

Ductwork Pressure Drop Report

Location	Level	Node	Type	Series	Product	Size	L [m]	Insulation	qv set [m³/h]	qv [m³/h]	v [m/s]	dpt [Pa]	K factor	dp/L [Pa/m]	pt [Pa]	pst [Pa]	adj.	qv [%]	Warnings
	Level 1	5	SUPPLY		PCA-100+MB	100			47	47	1.7	20.0			20.0		3.2	100	
	Level 1		DUCT	Lindab SR St	SR-100	100	1.8		47	47	1.7	1.0		0.54	21.0	19.3			
	Level 1	6	SUPPLY		PCA-100+MB	100			47	47	1.7	20.0			20.0		3.2	100	

Figure C.15: Pressure Loss of traditional ventilation system calculated by MagiCAD

MagiCAD

Ductwork Pressure Drop Report

Location	Level	Node	Type	Series	Product	Size	L [m]	Insulation	qv set [m³/h]	qv [m³/h]	v [m/s]	dpt [Pa]	K factor	dp/L [Pa/m]	pt [Pa]	pst [Pa]	adj.	qv [%]	Warnings
	Level 1		DUCT	Lindab SR St	SR-80	80	1.5		75	75	4.1	5.4		3.75	40.6	30.3			
	Level 1	5	SUPPLY		NR19-S-300x	80			75	75	4.1	35.1			35.1		89	100	

Figure C.22: Pressure Loss of HVV system calculated by MagiCAD

MagiCAD

Hydronic Network Pressure Drop Report

Project Information

Software version:	MagiCAD for Revit 2023	Calculation date:	10/01/2024 22:10
Project name:	Project Name	Project number:	Project Number
Project address:	Enter address in Project Information	Client name:	Owner
Project issue date:	Issue Date	Organization name:	
Organization description:		Author:	

Project Calculation Data

		Systems:	Heating supply / Heating return
Total pressure:	13.836 kPa	Total flow:	0.07477 l/s
Fluid type:	Water	Fluid temperature:	70 / 40 °C
Fluid density:	978 / 992.3 kg/m3	Fluid dyn. viscosity:	0.00040000 / 0.00065000 Pa*s
Fluid spec. heat capacity:	4180 / 4180 J/kg*K	Volume of the system:	165.8 l
Pipe series:	Standard / Material	Thermal conductivity:	
Steel pipe Fe-35:	Default / Metal	30.00000 W/m*K:	

Calculation Input Values

Pressure drop standard(s): Default

Calculation Results / Supply

Location	Level	Node	Type	Series	Product	Size	L [m]	Insulation	P [W]	qv [l/s]	v [m/s]	dp/L [Pa/m]	dpt [kPa]	K factor	pt [kPa]	adj.	Warnings
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	0.1		8400	0.07477	0.32	93.6	0.005		13.836		
	Level 4		STOPVALVE	Fe-35	SV-1-15	15			8400	0.07477			0.022		13.831		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	0.0		8400	0.07477	0.32	93.6	0.002		13.809		
	Level 4		STOPVALVE	Fe-35	RVR 15	15			8400	0.07477			4.290		13.807		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	0.0		8400	0.07477	0.32	93.6	0.003		9.517		
	Level 1	77	BRANCH	Fe-35	MAGI-FE-T1-1	15/15			8400	0.07477	0.32		0.049	1.000	9.513		
	Level 1		PIPE	Fe-35	MAGI-FE-15	15	3.7		2100	0.01869	0.08	7.9	0.029		5.167		
	Level 1		BEND-90	Fe-35	MAGI-FE-B1-1	15			2100	0.01869	0.08		0.001	0.476	5.137		
	Level 1		PIPE	Fe-35	MAGI-FE-15	15	0.4		2100	0.01869	0.08	7.9	0.003		5.136		
	Level 1	68	BRANCH	Fe-35	MAGI-FE-T1-1	15/15			2100	0.01869	0.08		0.003	1.000	5.133		
	Level 1		PIPE	Fe-35	MAGI-FE-15	15	0.4		700	0.00567	0.02	1.0	0.000		5.059		
	Level 1		BEND-90	Fe-35	MAGI-FE-B1-1	15			700	0.00567	0.02		0.000	0.476	5.059		
	Level 1		PIPE	Fe-35	MAGI-FE-15	15	0.1		700	0.00567	0.02	1.0	0.000		5.058		
	Level 1	69	RADIATOR V	Fe-35	Calypso TRV-	15			700	0.00567			5.000		5.058	4.0	
	Level 1	70	HEATING: RA		C22-450-1600	15			700	0.00567					0.058		
	Level 1		PIPE	Fe-35	MAGI-FE-15	15	6.8		1400	0.01303	0.06	3.7	0.025		5.133		

1

Figure C.16: Pressure Loss of heating system calculated by MagiCAD

MagiCAD

Hydronic Network Pressure Drop Report

Location	Level	Node	Type	Series	Product	Size	L [m]	Insulation	P [W]	qv [l/s]	v [m/s]	dp/L [Pa/m]	dpt [kPa]	K factor	pt [kPa]	adj.	Warnings
	Level 1		BEND-90	Fe-35	MAGI-FE-B1-1	15			1400	0.01303	0.06		0.001	0.476	5.107		
	Level 1		PIPE	Fe-35	MAGI-FE-15	15	0.8		1400	0.01303	0.06	3.7	0.003		5.106		
	Level 1	71	BRANCH	Fe-35	MAGI-FE-T1-1	15/15			1400	0.01303	0.06		0.002	1.000	5.104		
	Level 1		PIPE	Fe-35	MAGI-FE-15	15	0.4		700	0.00567	0.02	1.0	0.000		5.089		
	Level 1		BEND-90	Fe-35	MAGI-FE-B1-1	15			700	0.00567	0.02		0.000	0.476	5.089		
	Level 1		PIPE	Fe-35	MAGI-FE-15	15	0.1		700	0.00567	0.02	1.0	0.000		5.089		
	Level 1	72	RADIATOR V	Fe-35	Calypso TRV-	15			700	0.00567			5.000		5.089	4.0	
	Level 1	73	HEATING: RA		C33-450-1400	15			700	0.00567					0.089		
	Level 1		PIPE	Fe-35	MAGI-FE-15	15	3.9		700	0.00736	0.03	1.3	0.005		5.104		
	Level 1	74	BRANCH	Fe-35	MAGI-FE-T1-1	15/15			700	0.00736	0.03		0.000	1.000	5.098		
	Level 1		PIPE	Fe-35	MAGI-FE-15	15	0.4		700	0.00567	0.02	1.0	0.000		5.098		
	Level 1		BEND-90	Fe-35	MAGI-FE-B1-1	15			700	0.00567	0.02		0.000	0.476	5.097		
	Level 1		PIPE	Fe-35	MAGI-FE-15	15	0.2		700	0.00567	0.02	1.0	0.000		5.097		
	Level 1	75	RADIATOR V	Fe-35	Calypso TRV-	15			700	0.00567			5.000		5.097	4.0	
	Level 1	76	HEATING: RA		C33-450-1400	15			700	0.00567					0.097		
	Level 1		PIPE	Fe-35	MAGI-FE-15	15	2.0			0.00169	0.01	0.3	0.001		5.080		
	Level 1		BEND-90	Fe-35	MAGI-FE-B1-1	15				0.00169	0.01		0.000	0.476	5.080		
	Level 1		PIPE	Fe-35	MAGI-FE-15	15	4.4			0.00169	0.01	0.3	0.001		5.080		
	Level 1		BEND-90	Fe-35	MAGI-FE-B1-1	15				0.00169	0.01		0.000	0.476	5.078		
	Level 1		PIPE	Fe-35	MAGI-FE-15	15	1.1			0.00169	0.01	0.3	0.000		5.078		
	Level 1		BEND-90	Fe-35	MAGI-FE-B1-1	15				0.00169	0.01		0.000	0.476	5.078		
	Level 1		PIPE	Fe-35	MAGI-FE-15	15	0.0			0.00169	0.01	0.3	0.000		5.078		
	Level 1		BEND-90	Fe-35	MAGI-FE-B1-1	15				0.00169	0.01		0.000	0.476	5.078		
	Level 1		PIPE	Fe-35	MAGI-FE-15	15	0.6			0.00169	0.01	0.3	0.000		5.078		
	Level 1	78	RADIATOR V	Fe-35	Calypso TRV-	15				0.00169			5.000		5.078	1.8	
	Level 1		PIPE	Fe-35	MAGI-FE-15	15	0.0			0.00169	0.01	0.3	0.000		0.078		
	Level 1	79	HEATING: RA		NEV0805	15				0.00169					0.078		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	3.0		6300	0.05608	0.24	55.4	0.166		9.513		
	Level 4		STOPVALVE	Fe-35	RVR 15	15			6300	0.05608			2.413		9.347		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	0.1		6300	0.05608	0.24	55.4	0.004		6.934		
	Level 2	80	BRANCH	Fe-35	MAGI-FE-T1-1	15/15			6300	0.05608	0.24		0.028	1.000	6.930		
	Level 2		PIPE	Fe-35	MAGI-FE-15	15	3.7		2100	0.01869	0.08	7.9	0.029		5.369		
	Level 2		BEND-90	Fe-35	MAGI-FE-B1-1	15			2100	0.01869	0.08		0.001	0.476	5.340		
	Level 2		PIPE	Fe-35	MAGI-FE-15	15	0.5		2100	0.01869	0.08	7.9	0.004		5.338		
	Level 2	68	BRANCH	Fe-35	MAGI-FE-T1-1	15/15			2100	0.01869	0.08		0.003	1.000	5.335		
	Level 2		PIPE	Fe-35	MAGI-FE-15	15	0.4		700	0.00567	0.02	1.0	0.000		5.262		
	Level 2		BEND-90	Fe-35	MAGI-FE-B1-1	15			700	0.00567	0.02		0.000	0.476	5.261		
	Level 2		PIPE	Fe-35	MAGI-FE-15	15	0.1		700	0.00567	0.02	1.0	0.000		5.261		
	Level 2	69	RADIATOR V	Fe-35	Calypso TRV-	15			700	0.00567			5.000		5.261	4.0	
	Level 2	70	HEATING: RA		C22-450-1400	15			700	0.00567					0.261		

2

Figure C.17: Pressure Loss of heating system calculated by MagiCAD

MagiCAD

Hydronic Network Pressure Drop Report

Location	Level	Node	Type	Series	Product	Size	L [m]	Insulation	P [W]	qv [l/s]	v [m/s]	dp/L [Pa/m]	dpt [kPa]	K factor	pt [kPa]	adj.	Warnings
	Level 2		PIPE	Fe-35	MAGI-FE-15	15	6.7		1400	0.01303	0.06	3.7	0.025		5.335		
	Level 2		BEND-90	Fe-35	MAGI-FE-B1-1	15			1400	0.01303	0.06		0.001	0.476	5.309		
	Level 2		PIPE	Fe-35	MAGI-FE-15	15	0.8		1400	0.01303	0.06	3.7	0.003		5.309		
	Level 2	71	BRANCH	Fe-35	MAGI-FE-T1-1	15/15			1400	0.01303	0.06		0.002	1.000	5.306		
	Level 2		PIPE	Fe-35	MAGI-FE-15	15	0.4		700	0.00567	0.02	1.0	0.000		5.292		
	Level 2		BEND-90	Fe-35	MAGI-FE-B1-1	15			700	0.00567	0.02		0.000	0.476	5.291		
	Level 2		PIPE	Fe-35	MAGI-FE-15	15	0.2		700	0.00567	0.02	1.0	0.000		5.291		
	Level 2	72	RADIATOR V	Fe-35	Calypso TRV-	15			700	0.00567			5.000		5.291	4.0	
	Level 2	73	HEATING: RA		C33-450-1200	15			700	0.00567					0.291		
	Level 2		PIPE	Fe-35	MAGI-FE-15	15	3.9		700	0.00736	0.03	1.3	0.005		5.306		
	Level 2	74	BRANCH	Fe-35	MAGI-FE-T1-1	15/15			700	0.00736	0.03		0.000	1.000	5.301		
	Level 2		PIPE	Fe-35	MAGI-FE-15	15	0.4		700	0.00567	0.02	1.0	0.000		5.300		
	Level 2		BEND-90	Fe-35	MAGI-FE-B1-1	15			700	0.00567	0.02		0.000	0.476	5.300		
	Level 2		PIPE	Fe-35	MAGI-FE-15	15	0.3		700	0.00567	0.02	1.0	0.000		5.300		
	Level 2	75	RADIATOR V	Fe-35	Calypso TRV-	15			700	0.00567			5.000		5.299	4.0	
	Level 2	76	HEATING: RA		C33-450-1200	15			700	0.00567					0.299		
	Level 2		PIPE	Fe-35	MAGI-FE-15	15	2.0			0.00169	0.01	0.3	0.001		5.283		
	Level 2		BEND-90	Fe-35	MAGI-FE-B1-1	15				0.00169	0.01		0.000	0.476	5.282		
	Level 2		PIPE	Fe-35	MAGI-FE-15	15	4.4			0.00169	0.01	0.3	0.001		5.282		
	Level 2		BEND-90	Fe-35	MAGI-FE-B1-1	15				0.00169	0.01		0.000	0.476	5.281		
	Level 2		PIPE	Fe-35	MAGI-FE-15	15	1.1			0.00169	0.01	0.3	0.000		5.281		
	Level 2		BEND-90	Fe-35	MAGI-FE-B1-1	15				0.00169	0.01		0.000	0.476	5.280		
	Level 2		PIPE	Fe-35	MAGI-FE-15	15	0.0			0.00169	0.01	0.3	0.000		5.280		
	Level 2		BEND-90	Fe-35	MAGI-FE-B1-1	15				0.00169	0.01		0.000	0.476	5.280		
	Level 2		PIPE	Fe-35	MAGI-FE-15	15	0.6			0.00169	0.01	0.3	0.000		5.280		
	Level 2	81	RADIATOR V	Fe-35	Calypso TRV-	15				0.00169			5.000		5.280	1.8	
	Level 2		PIPE	Fe-35	MAGI-FE-15	15	0.0			0.00169	0.01	0.3	0.000		0.280		
	Level 2	82	HEATING: RA		NEV0805	15				0.00169					0.280		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	3.0		4200	0.03739	0.16	26.9	0.080		6.930		
	Level 4		STOPVALVE	Fe-35	RVR 15	15			4200	0.03739			1.073		6.850		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	0.1		4200	0.03739	0.16	26.9	0.003		5.777		
	Level 3	83	BRANCH	Fe-35	MAGI-FE-T1-1	15/15			4200	0.03739	0.16		0.012	1.000	5.775		
	Level 3		PIPE	Fe-35	MAGI-FE-15	15	3.7		2100	0.01869	0.08	7.9	0.029		5.468		
	Level 3		BEND-90	Fe-35	MAGI-FE-B1-1	15			2100	0.01869	0.08		0.001	0.476	5.438		
	Level 3		PIPE	Fe-35	MAGI-FE-15	15	0.5		2100	0.01869	0.08	7.9	0.004		5.437		
	Level 3	68	BRANCH	Fe-35	MAGI-FE-T1-1	15/15			2100	0.01869	0.08		0.003	1.000	5.433		
	Level 3		PIPE	Fe-35	MAGI-FE-15	15	0.4		700	0.00567	0.02	1.0	0.000		5.360		
	Level 3		BEND-90	Fe-35	MAGI-FE-B1-1	15			700	0.00567	0.02		0.000	0.476	5.359		
	Level 3		PIPE	Fe-35	MAGI-FE-15	15	0.1		700	0.00567	0.02	1.0	0.000		5.359		
	Level 3	69	RADIATOR V	Fe-35	Calypso TRV-	15			700	0.00567			5.000		5.359	4.0	

3

Figure C.18: Pressure Loss of heating system calculated by MagiCAD

MagiCAD

Hydronic Network Pressure Drop Report

Location	Level	Node	Type	Series	Product	Size	L [m]	Insulation	P [W]	qv [l/s]	v [m/s]	dp/L [Pa/m]	dpt [kPa]	K factor	pt [kPa]	adj.	Warnings
	Level 3	70	HEATING: RA		C22-450-1400	15			700	0.00567					0.359		
	Level 3		PIPE	Fe-35	MAGI-FE-15	15	6.7		1400	0.01303	0.06	3.7	0.025		5.433		
	Level 3		BEND-90	Fe-35	MAGI-FE-B1-1	15			1400	0.01303	0.06		0.001	0.476	5.408		
	Level 3		PIPE	Fe-35	MAGI-FE-15	15	0.8		1400	0.01303	0.06	3.7	0.003		5.407		
	Level 3	71	BRANCH	Fe-35	MAGI-FE-T1-1	15/15			1400	0.01303	0.06		0.002	1.000	5.404		
	Level 3		PIPE	Fe-35	MAGI-FE-15	15	0.4		700	0.00567	0.02	1.0	0.000		5.390		
	Level 3		BEND-90	Fe-35	MAGI-FE-B1-1	15			700	0.00567	0.02		0.000	0.476	5.390		
	Level 3		PIPE	Fe-35	MAGI-FE-15	15	0.2		700	0.00567	0.02	1.0	0.000		5.390		
	Level 3	72	RADIATOR V	Fe-35	Calypso TRV-	15			700	0.00567			5.000		5.389	4.0	
	Level 3	73	HEATING: RA		C33-450-1200	15			700	0.00567					0.389		
	Level 3		PIPE	Fe-35	MAGI-FE-15	15	3.9		700	0.00736	0.03	1.3	0.005		5.404		
	Level 3	74	BRANCH	Fe-35	MAGI-FE-T1-1	15/15			700	0.00736	0.03		0.000	1.000	5.399		
	Level 3		PIPE	Fe-35	MAGI-FE-15	15	0.4		700	0.00567	0.02	1.0	0.000		5.399		
	Level 3		BEND-90	Fe-35	MAGI-FE-B1-1	15			700	0.00567	0.02		0.000	0.476	5.398		
	Level 3		PIPE	Fe-35	MAGI-FE-15	15	0.3		700	0.00567	0.02	1.0	0.000		5.398		
	Level 3	75	RADIATOR V	Fe-35	Calypso TRV-	15			700	0.00567			5.000		5.398	4.0	
	Level 3	76	HEATING: RA		C33-450-1200	15			700	0.00567					0.398		
	Level 3		PIPE	Fe-35	MAGI-FE-15	15	2.0			0.00169	0.01	0.3	0.001		5.381		
	Level 3		BEND-90	Fe-35	MAGI-FE-B1-1	15				0.00169	0.01		0.000	0.476	5.380		
	Level 3		PIPE	Fe-35	MAGI-FE-15	15	4.4			0.00169	0.01	0.3	0.001		5.380		
	Level 3		BEND-90	Fe-35	MAGI-FE-B1-1	15				0.00169	0.01		0.000	0.476	5.379		
	Level 3		PIPE	Fe-35	MAGI-FE-15	15	1.1			0.00169	0.01	0.3	0.000		5.379		
	Level 3		BEND-90	Fe-35	MAGI-FE-B1-1	15				0.00169	0.01		0.000	0.476	5.379		
	Level 3		PIPE	Fe-35	MAGI-FE-15	15	0.0			0.00169	0.01	0.3	0.000		5.379		
	Level 3		BEND-90	Fe-35	MAGI-FE-B1-1	15				0.00169	0.01		0.000	0.476	5.379		
	Level 3		PIPE	Fe-35	MAGI-FE-15	15	0.6			0.00169	0.01	0.3	0.000		5.379		
	Level 3	84	RADIATOR V	Fe-35	Calypso TRV-	15				0.00169			5.000		5.378	1.8	
	Level 3		PIPE	Fe-35	MAGI-FE-15	15	0.0			0.00169	0.01	0.3	0.000		0.378		
	Level 3	85	HEATING: RA		NEV0805	15				0.00169					0.378		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	2.8		2100	0.01869	0.08	7.9	0.022		5.775		
	Level 4		STOPVALVE	Fe-35	RVR 15	15			2100	0.01869			0.268		5.752		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	0.1		2100	0.01869	0.08	7.9	0.000		5.484		
	Level 4		BEND-90	Fe-35	MAGI-FE-B1-1	15			2100	0.01869	0.08		0.001	0.476	5.484		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	3.7		2100	0.01869	0.08	7.9	0.029		5.482		
	Level 4		BEND-90	Fe-35	MAGI-FE-B1-1	15			2100	0.01869	0.08		0.001	0.476	5.453		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	0.5		2100	0.01869	0.08	7.9	0.004		5.451		
	Level 4	68	BRANCH	Fe-35	MAGI-FE-T1-1	15/15			2100	0.01869	0.08		0.003	1.000	5.448		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	0.6		700	0.00567	0.02	1.0	0.001		5.375		
	Level 4		BEND-90	Fe-35	MAGI-FE-B1-1	15			700	0.00567	0.02		0.000	0.476	5.374		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	0.1		700	0.00567	0.02	1.0	0.000		5.374		

4

Figure C.19: Pressure Loss of heating system calculated by MagiCAD

MagiCAD

Hydronic Network Pressure Drop Report

Location	Level	Node	Type	Series	Product	Size	L [m]	Insulation	P [W]	qv [l/s]	v [m/s]	dp/L [Pa/m]	dpt [kPa]	K factor	pt [kPa]	adj.	Warnings
	Level 4	69	RADIATOR V	Fe-35	Calypso TRV-	15			700	0.00567			5.000		5.374	4.0	
	Level 4	70	HEATING: RA		C22-450-1400	15			700	0.00567					0.374		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	6.7		1400	0.01303	0.06	3.7	0.025		5.448		
	Level 4		BEND-90	Fe-35	MAGI-FE-B1-1	15			1400	0.01303	0.06		0.001	0.476	5.422		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	0.8		1400	0.01303	0.06	3.7	0.003		5.422		
	Level 4	71	BRANCH	Fe-35	MAGI-FE-T1-1	15/15			1400	0.01303	0.06		0.002	1.000	5.419		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	0.6		700	0.00567	0.02	1.0	0.001		5.405		
	Level 4		BEND-90	Fe-35	MAGI-FE-B1-1	15			700	0.00567	0.02		0.000	0.476	5.404		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	0.1		700	0.00567	0.02	1.0	0.000		5.404		
	Level 4	72	RADIATOR V	Fe-35	Calypso TRV-	15			700	0.00567			5.000		5.404	4.0	
	Level 4	73	HEATING: RA		C33-450-1400	15			700	0.00567					0.404		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	3.9		700	0.00736	0.03	1.3	0.005		5.419		
	Level 4	74	BRANCH	Fe-35	MAGI-FE-T1-1	15/15			700	0.00736	0.03		0.000	1.000	5.414		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	0.6		700	0.00567	0.02	1.0	0.001		5.413		
	Level 4		BEND-90	Fe-35	MAGI-FE-B1-1	15			700	0.00567	0.02		0.000	0.476	5.413		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	0.2		700	0.00567	0.02	1.0	0.000		5.412		
	Level 4	75	RADIATOR V	Fe-35	Calypso TRV-	15			700	0.00567			5.000		5.412	4.0	
	Level 4	76	HEATING: RA		C33-450-1400	15			700	0.00567					0.412		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	2.0			0.00169	0.01	0.3	0.001		5.395		
	Level 4		BEND-90	Fe-35	MAGI-FE-B1-1	15				0.00169	0.01		0.000	0.476	5.395		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	4.4			0.00169	0.01	0.3	0.001		5.395		
	Level 4		BEND-90	Fe-35	MAGI-FE-B1-1	15				0.00169	0.01		0.000	0.476	5.393		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	1.1			0.00169	0.01	0.3	0.000		5.393		
	Level 4		BEND-90	Fe-35	MAGI-FE-B1-1	15				0.00169	0.01		0.000	0.476	5.393		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	0.0			0.00169	0.01	0.3	0.000		5.393		
	Level 4		BEND-90	Fe-35	MAGI-FE-B1-1	15				0.00169	0.01		0.000	0.476	5.393		
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	0.8			0.00169	0.01	0.3	0.000		5.393		
	Level 4	86	RADIATOR V	Fe-35	Calypso TRV-	15				0.00169			5.000		5.393	1.8	
	Level 4		PIPE	Fe-35	MAGI-FE-15	15	0.0			0.00169	0.01	0.3	0.000		0.393		
	Level 4	87	HEATING: RA		NEV0805	15				0.00169					0.393		

5

Figure C.20: Pressure Loss of heating system calculated by MagiCAD

MagiCAD

Ductwork Pressure Drop Report

Project Information

Software version:	MagiCAD for Revit 2023	Calculation date:	10/01/2024 22:12
Project name:	Project Name	Project number:	Project Number
Project address:	Enter address in Project Information	Client name:	Owner
Project issue date:	Issue Date	Organization name:	
Organization description:		Author:	

Project Calculation Data

Systems:	- / - / - / -		
Total flow:	200 m³/h	Total pressure:	63.2 Pa

Calculation Input Values

Air Density:	1.20 kg/m3	Air Dynamic Viscosity:	0.00001813 Pa*s
Min. dp air devices:	20.0 Pa		

Calculation Results / Supply

Location	Level	Node	Type	Series	Product	Size	L [m]	Insulation	qv set [m³/h]	qv [m³/h]	v [m/s]	dpt [Pa]	K factor	dp/L [Pa/m]	pt [Pa]	pst [Pa]	adj.	qv [%]	Warnings
	Level 1	6	AHE/AHU		VEX40T CLA				200	200					0				
	Level 1		DUCT	Lindab SR St	SR-160	160	0.1		200	200	2.8	0.1		0.74	63.2	58.7			
	Level 1		BEND-90	Lindab SR St	BU_DK-*-*0,1	160			200	200	2.8	2.0	0.442		63.2				
	Level 1		DUCT	Lindab SR St	SR-160	160	0.1		200	200	2.8	0.1		0.74	61.1	56.6			
	Level 1		REDUCER	Lindab SR St	RCFU_DK-*-*	160/125			200	200	2.8	0.4	0.035		61.0				
	Level 1	7	BOX		MHU 125 76	125 (L)			200	200		7.8			60.6				
	Level 1		DUCT	Lindab SR St	SR-80	80	0.3		50	50	2.8	0.6		1.78	28.8	24.2			
	Level 1		BEND-90	Lindab SR St	BU-80-90	80			50	50	2.8	2.4	0.520		28.2				
	Level 1		DUCT	Lindab SR St	SR-80	80	0.3		50	50	2.8	0.5		1.78	25.8	21.2			
	Level 1		BEND-90	Lindab SR St	BU-80-90	80			50	50	2.8	2.4	0.520		25.3				
	Level 1		DUCT	Lindab SR St	SR-80	80	1.6		50	50	2.8	2.9		1.78	22.9	18.3			
	Level 1	8	SUPPLY		NR19-S-300x	80			50	50	2.8	20.0			20.0		72	100	
	Level 1		DUCT	Lindab SR St	SR-80	80	0.5		75	75	4.1	1.8		3.75	50.9	40.6			
	Level 1		BEND-90	Lindab SR St	BU-80-90	80			75	75	4.1	4.8	0.464		49.2				
	Level 1		DUCT	Lindab SR St	SR-80	80	0.5		75	75	4.1	1.9		3.75	44.4	34.1			
	Level 1		BEND-25	Lindab SR St	BU_DK-*-*0,1	80			75	75	4.1	1.3	0.128		42.5				
	Level 1		DUCT	Lindab SR St	SR-80	80	0.2		75	75	4.1	0.9		3.75	41.2	30.9			
	Level 1		BEND-25	Lindab SR St	BU_DK-*-*0,1	80			75	75	4.1	1.3	0.128		40.3				
	Level 1		DUCT	Lindab SR St	SR-80	80	1.0		75	75	4.1	3.8		3.75	39.0	28.7			
	Level 1	5	SUPPLY		NR19-S-300x	80			75	75	4.1	35.1			35.1		89	100	
	Level 1		DUCT	Lindab SR St	SR-80	80	0.3		75	75	4.1	1.3		3.75	46.7	36.4			
	Level 1		BEND-90	Lindab SR St	BU-80-90	80			75	75	4.1	4.8	0.464		45.4				

1

Figure C.21: Pressure Loss of HVV system calculated by MagiCAD

Appendix D

Appendix D

This appendix includes all simulation results conducted in BSIM, providing an overview of the outcomes from various scenarios.

Baseline | Traditional | Set Point: 20°C | Heat Recovery: 0.92 | Moisture Recovery: -													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-679.59	-95.55	-87.16	-102.23	-61.75	-32.99	-24.3	-16.93	-15.24	-19.55	-50.09	-78.84	-94.96
qVenting	-0.1	0	0	0	0	0	0	-0.1	0	0	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	0	0	0	0	0	0	0	0	0	0	0	0	0
qEquipment	0	0	0	0	0	0	0	0	0	0	0	0	0
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-2278.51	-348.59	-313.33	-361.06	-196.03	-85.87	-62.19	-23.96	-19.67	-49.01	-177.85	-287.28	-353.67
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	1919.65	388.18	341.24	380.86	154.46	2.15	-36.21	-83.45	-73.4	-15.78	157.3	310.18	394.11
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	19.9	20	20	20	20	18.2	19.4	21.3	21	18.6	20	20	20
AirChange(/h)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Rel. Moisture(%)	41.1	24.6	24.7	22.2	32.7	48.3	57.4	60.9	59.6	59.8	46	31.1	26.1
Co2(ppm)	350	350	350	350	350	350	350	350	350	350	350	350	350
PAQ(-)	0.5	0.7	0.7	0.7	0.6	0.5	0.3	0.1	0.2	0.4	0.4	0.6	0.7
Hours > 21	811	0	0	0	0	1	115	369	311	15	0	0	0
Hours > 26	1	0	0	0	0	0	0	1	0	0	0	0	0
Hours > 27	0	0	0	0	0	0	0	0	0	0	0	0	0
Hours < 19.9	2040	0	0	0	0	650	468	118	147	652	5	0	0
FanPow	327.04	27.78	25.09	27.78	26.88	27.78	26.88	27.78	27.78	26.88	27.78	26.88	27.78
HtRec	6102.9	888.08	809.8	950.81	571.99	297.76	190.26	76.12	68.73	164.77	467.95	733.52	883.1
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	2615.49	466.07	412.6	464.4	201.94	0	0	0	0	0	188.95	371.62	470.88
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Baseline | Traditional | Set Point: 22°C | Heat Recovery: 0.92 | Moisture Recovery: -													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-742.64	-104.74	-95.42	-111.28	-70.84	-33.27	-24.3	-16.93	-15.24	-19.55	-59.43	-87.72	-103.92
qVenting	-0.1	0	0	0	0	0	0	-0.1	0	0	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	0	0	0	0	0	0	0	0	0	0	0	0	0
qEquipment	0	0	0	0	0	0	0	0	0	0	0	0	0
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-2597.62	-402.82	-362.05	-412.26	-230.84	-82.59	-62.19	-23.96	-19.67	-49.01	-218.34	-329.67	-404.22
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	2301.8	451.59	398.23	441.11	198.36	-0.85	-36.21	-83.45	-73.4	-15.78	207.12	361.45	453.63
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	21	22	22	22	22	18.3	19.4	21.3	21	18.6	22	22	22
AirChange(/h)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Rel. Moisture(%)	39.1	21.7	21.8	19.6	29	48.1	57.4	60.9	59.6	59.8	40.7	27.5	23.1
Co2(ppm)	350	350	350	350	350	350	350	350	350	350	350	350	350
PAQ(-)	0.5	0.6	0.6	0.7	0.5	0.5	0.3	0.1	0.2	0.4	0.4	0.5	0.6
Hours > 21	5893	744	672	744	720	2	115	369	311	15	737	720	744
Hours > 26	1	0	0	0	0	0	0	1	0	0	0	0	0
Hours > 27	0	0	0	0	0	0	0	0	0	0	0	0	0
Hours < 19.9	2032	0	0	0	0	642	468	118	147	652	5	0	0
FanPow	327.04	27.78	25.09	27.78	26.88	27.78	26.88	27.78	27.78	26.88	27.78	26.88	27.78
HtRec	6721.7	979.06	891.87	1039.63	662.2	298.96	190.26	76.12	68.73	164.77	558.08	820.79	971.23
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	3086.88	543.21	481.77	539.38	255.12	0	0	0	0	0	249.84	435.4	544.33
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Baseline | Traditional | Set Point: 20°C | Heat Recovery: 0.85 | Moisture Recovery: 0.86

	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-679.03	-95.55	-87.16	-102.23	-61.75	-32.95	-24.22	-16.73	-15.06	-19.5	-50.09	-78.84	-94.96
qVenting	-0.05	0	0	0	0	0	0	-0.05	0	0	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	0	0	0	0	0	0	0	0	0	0	0	0	0
qEquipment	0	0	0	0	0	0	0	0	0	0	0	0	0
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-2275.12	-348.59	-313.33	-361.06	-196.02	-85.63	-61.62	-22.73	-18.61	-48.73	-177.85	-287.28	-353.67
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	1915.64	388.18	341.24	380.86	154.45	1.87	-36.86	-84.94	-74.65	-16.11	157.3	310.18	394.11
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	19.9	20	20	20	20	18.2	19.3	21.3	21	18.6	20	20	20
AirChange(/h)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Rel. Moisture(%)	41.1	24.5	24.6	22.1	32.7	48.1	57.6	61	59.6	59.8	46.1	31.1	25.9
Co2(ppm)	350	350	350	350	350	350	350	350	350	350	350	350	350
PAQ(-)	0.5	0.7	0.7	0.7	0.6	0.5	0.3	0.1	0.2	0.4	0.4	0.6	0.7
Hours > 21	782	0	0	0	0	1	109	357	301	14	0	0	0
Hours > 26	0	0	0	0	0	0	0	0	0	0	0	0	0
Hours > 27	0	0	0	0	0	0	0	0	0	0	0	0	0
Hours < 19.9	2059	0	0	0	0	655	472	124	150	653	5	0	0
FanPow	163.52	13.89	12.54	13.89	13.44	13.89	13.44	13.89	13.89	13.44	13.89	13.44	13.89
HtRec	5783.95	838.29	764.49	896.01	539.84	282.04	185.63	79.51	72.44	161.86	439.48	691.5	832.85
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	3006.47	522.81	464.19	526.14	240.78	0	0	0	0	0	224.34	420.36	528.09
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Baseline | Traditional | Set Point: 22°C | Heat Recovery: 0.85 | Moisture Recovery: 0.86

	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-742.07	-104.74	-95.42	-111.28	-70.84	-33.23	-24.22	-16.73	-15.06	-19.5	-59.42	-87.72	-103.92
qVenting	-0.05	0	0	0	0	0	0	-0.05	0	0	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	0	0	0	0	0	0	0	0	0	0	0	0	0
qEquipment	0	0	0	0	0	0	0	0	0	0	0	0	0
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-2594.24	-402.82	-362.05	-412.26	-230.84	-82.35	-61.62	-22.73	-18.61	-48.73	-218.34	-329.67	-404.22
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	2297.81	451.59	398.23	441.11	198.36	-1.13	-36.86	-84.94	-74.65	-16.11	207.12	361.45	453.63
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	21	22	22	22	22	18.2	19.3	21.3	21	18.6	22	22	22
AirChange(/h)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Rel. Moisture(%)	39.1	21.6	21.8	19.5	28.9	47.9	57.6	61	59.6	59.8	40.8	27.5	23
Co2(ppm)	350	350	350	350	350	350	350	350	350	350	350	350	350
PAQ(-)	0.5	0.6	0.6	0.7	0.5	0.5	0.3	0.1	0.2	0.4	0.4	0.5	0.6
Hours > 21	5864	744	672	744	720	2	109	357	301	14	737	720	744
Hours > 26	0	0	0	0	0	0	0	0	0	0	0	0	0
Hours > 27	0	0	0	0	0	0	0	0	0	0	0	0	0
Hours < 19.9	2054	0	0	0	0	650	472	124	150	653	5	0	0
FanPow	163.52	13.89	12.54	13.89	13.44	13.89	13.44	13.89	13.89	13.44	13.89	13.44	13.89
HtRec	6357.49	921.61	839.59	979.09	622.94	284.09	185.63	79.51	72.44	161.86	524.03	772.26	914.46
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	3523.15	607.61	540.33	606.87	301.09	0	0	0	0	0	290.82	490.65	608.06
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Baseline | HVV| Set Point: 20°C | Heat Recovery: 0.9 | Moisture Recovery: -													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-679.59	-95.55	-87.16	-102.23	-61.75	-32.99	-24.3	-16.93	-15.24	-19.55	-50.09	-78.84	-94.96
qVenting	-0.1	0	0	0	0	0	0	-0.1	0	0	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	0	0	0	0	0	0	0	0	0	0	0	0	0
qEquipment	0	0	0	0	0	0	0	0	0	0	0	0	0
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-2278.51	-348.59	-313.33	-361.06	-196.03	-85.87	-62.19	-23.96	-19.67	-49.01	-177.85	-287.28	-353.67
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	1919.65	388.18	341.24	380.86	154.46	2.15	-36.21	-83.45	-73.4	-15.78	157.3	310.18	394.11
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	19.9	20	20	20	20	18.2	19.4	21.3	21	18.6	20	20	20
AirChange(/h)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Rel. Moisture(%)	41.1	24.6	24.7	22.2	32.7	48.3	57.4	60.9	59.6	59.8	46	31.1	26.1
Co2(ppm)	350	350	350	350	350	350	350	350	350	350	350	350	350
PAQ(-)	0.5	0.7	0.7	0.7	0.6	0.5	0.3	0.1	0.2	0.4	0.4	0.6	0.7
Hours > 21	811	0	0	0	0	1	115	369	311	15	0	0	0
Hours > 26	1	0	0	0	0	0	0	1	0	0	0	0	0
Hours > 27	0	0	0	0	0	0	0	0	0	0	0	0	0
Hours < 19.9	2040	0	0	0	0	650	468	118	147	652	5	0	0
FanPow	327.04	27.78	25.09	27.78	26.88	27.78	26.88	27.78	27.78	26.88	27.78	26.88	27.78
HtRec	6102.9	888.08	809.8	950.81	571.99	297.76	190.26	76.12	68.73	164.77	467.95	733.52	883.1
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	2615.49	466.07	412.6	464.4	201.94	0	0	0	0	0	188.95	371.62	470.88
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Baseline | HVV | Set Point: 22°C | Heat Recovery: 0.9 | Moisture Recovery: -													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-742.64	-104.74	-95.42	-111.28	-70.84	-33.27	-24.3	-16.93	-15.24	-19.55	-59.43	-87.72	-103.92
qVenting	-0.1	0	0	0	0	0	0	-0.1	0	0	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	0	0	0	0	0	0	0	0	0	0	0	0	0
qEquipment	0	0	0	0	0	0	0	0	0	0	0	0	0
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-2597.62	-402.82	-362.05	-412.26	-230.84	-82.59	-62.19	-23.96	-19.67	-49.01	-218.34	-329.67	-404.22
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	2301.8	451.59	398.23	441.11	198.36	-0.85	-36.21	-83.45	-73.4	-15.78	207.12	361.45	453.63
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	21	22	22	22	22	18.3	19.4	21.3	21	18.6	22	22	22
AirChange(/h)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Rel. Moisture(%)	39.1	21.7	21.8	19.6	29	48.1	57.4	60.9	59.6	59.8	40.7	27.5	23.1
Co2(ppm)	350	350	350	350	350	350	350	350	350	350	350	350	350
PAQ(-)	0.5	0.6	0.6	0.7	0.5	0.5	0.3	0.1	0.2	0.4	0.4	0.5	0.6
Hours > 21	5893	744	672	744	720	2	115	369	311	15	737	720	744
Hours > 26	1	0	0	0	0	0	0	1	0	0	0	0	0
Hours > 27	0	0	0	0	0	0	0	0	0	0	0	0	0
Hours < 19.9	2032	0	0	0	0	642	468	118	147	652	5	0	0
FanPow	327.04	27.78	25.09	27.78	26.88	27.78	26.88	27.78	27.78	26.88	27.78	26.88	27.78
HtRec	6721.7	979.06	891.87	1039.63	662.2	298.96	190.26	76.12	68.73	164.77	558.08	820.79	971.23
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	3086.88	543.21	481.77	539.38	255.12	0	0	0	0	0	249.84	435.4	544.33
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Baseline | HVV | Set Point: 20°C | Heat Recovery: 0.85 | Moisture Recovery: 0.86													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-679.03	-95.55	-87.16	-102.23	-61.75	-32.95	-24.22	-16.73	-15.06	-19.5	-50.09	-78.84	-94.96
qVenting	-0.05	0	0	0	0	0	0	-0.05	0	0	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	0	0	0	0	0	0	0	0	0	0	0	0	0
qEquipment	0	0	0	0	0	0	0	0	0	0	0	0	0
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-2275.12	-348.59	-313.33	-361.06	-196.02	-85.63	-61.62	-22.73	-18.61	-48.73	-177.85	-287.28	-353.67
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	1915.64	388.18	341.24	380.86	154.45	1.87	-36.86	-84.94	-74.65	-16.11	157.3	310.18	394.11
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	19.9	20	20	20	20	18.2	19.3	21.3	21	18.6	20	20	20
AirChange(/h)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Rel. Moisture(%)	41.1	24.5	24.6	22.1	32.7	48.1	57.6	61	59.6	59.8	46.1	31.1	25.9
Co2(ppm)	350	350	350	350	350	350	350	350	350	350	350	350	350
PAQ(-)	0.5	0.7	0.7	0.7	0.6	0.5	0.3	0.1	0.2	0.4	0.4	0.6	0.7
Hours > 21	782	0	0	0	0	1	109	357	301	14	0	0	0
Hours > 26	0	0	0	0	0	0	0	0	0	0	0	0	0
Hours > 27	0	0	0	0	0	0	0	0	0	0	0	0	0
Hours < 19.9	2059	0	0	0	0	655	472	124	150	653	5	0	0
FanPow	163.52	13.89	12.54	13.89	13.44	13.89	13.44	13.89	13.89	13.44	13.89	13.44	13.89
HtRec	5783.95	838.29	764.49	896.01	539.84	282.04	185.63	79.51	72.44	161.86	439.48	691.5	832.85
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	3006.47	522.81	464.19	526.14	240.78	0	0	0	0	0	224.34	420.36	528.09
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Baseline | HVV | Set Point: 22°C | Heat Recovery: 0.85 | Moisture Recovery: 0.86													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-742.07	-104.74	-95.42	-111.28	-70.84	-33.23	-24.22	-16.73	-15.06	-19.5	-59.42	-87.72	-103.92
qVenting	-0.05	0	0	0	0	0	0	-0.05	0	0	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	0	0	0	0	0	0	0	0	0	0	0	0	0
qEquipment	0	0	0	0	0	0	0	0	0	0	0	0	0
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-2594.24	-402.82	-362.05	-412.26	-230.84	-82.35	-61.62	-22.73	-18.61	-48.73	-218.34	-329.67	-404.22
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	2297.81	451.59	398.23	441.11	198.36	-1.13	-36.86	-84.94	-74.65	-16.11	207.12	361.45	453.63
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	21	22	22	22	22	18.2	19.3	21.3	21	18.6	22	22	22
AirChange(/h)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Rel. Moisture(%)	39.1	21.6	21.8	19.5	28.9	47.9	57.6	61	59.6	59.8	40.8	27.5	23
Co2(ppm)	350	350	350	350	350	350	350	350	350	350	350	350	350
PAQ(-)	0.5	0.6	0.6	0.7	0.5	0.5	0.3	0.1	0.2	0.4	0.4	0.5	0.6
Hours > 21	5864	744	672	744	720	2	109	357	301	14	737	720	744
Hours > 26	0	0	0	0	0	0	0	0	0	0	0	0	0
Hours > 27	0	0	0	0	0	0	0	0	0	0	0	0	0
Hours < 19.9	2054	0	0	0	0	650	472	124	150	653	5	0	0
FanPow	163.52	13.89	12.54	13.89	13.44	13.89	13.44	13.89	13.89	13.44	13.89	13.44	13.89
HtRec	6357.49	921.61	839.59	979.09	622.94	284.09	185.63	79.51	72.44	161.86	524.03	772.26	914.46
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	3523.15	607.61	540.33	606.87	301.09	0	0	0	0	0	290.82	490.65	608.06
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Elderly | Traditional | Set Point: 20°C | Heat Recovery: 0.92 | Moisture Recovery: -													
	Sum/Mean	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
qHeating	847.62	168.03	145.04	172.76	36.49	0	0	0	0	0	34.27	114.41	176.62
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-783.36	-95.91	-87.58	-103.2	-68.56	-52.5	-42	-30.3	-29.71	-39.6	-58.11	-80.42	-95.37
qVenting	-359.23	0	0	0	-1.14	-21.1	-57.7	-142	-120.5	-16.76	-0.14	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	789.73	67.07	60.58	67.07	64.91	67.07	64.91	67.07	67.07	64.91	67.07	64.91	67.07
qEquipment	2653.22	226.22	203.49	224.6	218.37	225.4	217.6	226.2	224.6	217.56	226.22	217.56	225.41
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-2952.04	-354.3	-319.7	-372.4	-248	-210	-169	-108	-112.1	-171.95	-225.3	-300.34	-360.7
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-1234.49	-67.13	-61.07	-71.26	-105.4	-125	-137	-137	-137.7	-138.5	-114.7	-72.07	-67.54
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	21.7	20.1	20.2	20.3	21.5	22.3	23.2	24.1	24	22.9	21.7	20.4	20.1
AirChange(/h)	0.9	0.7	0.7	0.7	0.7	0.8	1	1.5	1.4	0.8	0.7	0.7	0.7
Rel. Moisture(%)	38.6	**27.9**	**28**	**25.2**	**32.9**	**40.3**	**48**	**53.2**	**51.6**	**48.7**	**44.3**	**33.7**	**29.4**
Co2(ppm)	465.7	477.3	477	476.9	476.5	467.1	455.3	426.9	432	470.5	475.9	476	476.6
PAQ(-)	0.4	0.7	0.6	0.7	0.5	0.4	0.2	0	0.1	0.2	0.3	0.6	0.6
Hours > 21	4826	14	16	51	479	662	701	744	744	712	596	89	18
Hours > 26	112	0	0	0	0	0	15	53	39	5	0	0	0
Hours > 27	32	0	0	0	0	0	0	21	11	0	0	0	0
Hours < 19.9	2	0	2	0	0	0	0	0	0	0	0	0	0
FanPow	203.52	17.29	15.61	17.29	16.73	17.29	16.73	17.29	17.29	16.73	17.29	16.73	17.29
HtRec	3853.49	568.56	519.94	618.91	337.22	206.9	126	47.97	43.29	107.67	255.21	456.23	565.69
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Elderly | Traditional | Set Point: 22°C | Heat Recovery: 0.92 | Moisture Recovery: -													
	Sum/Mean	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
qHeating	1549.6	295.66	258.61	291.07	96.15	0	0	0	0	0	82.66	223.65	301.8
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-831.94	-104.7	-95.43	-111.5	-72.91	-52.5	-42	-30.3	-29.71	-39.6	-61.26	-87.93	-104.07
qVenting	-359.81	0	0	0	-1.37	-21.1	-57.7	-142	-120.5	-16.76	-0.49	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	789.73	67.07	60.58	67.07	64.91	67.07	64.91	67.07	67.07	64.91	67.07	64.91	67.07
qEquipment	2653.22	226.22	203.49	224.6	218.37	225.4	217.6	226.2	224.6	217.56	226.22	217.56	225.41
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-3279.57	-413.8	-372.55	-427.1	-274.4	-210	-169	-108	-112.1	-171.95	-249.5	-351.84	-418.93
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-1559.78	-126.4	-113.94	-126.6	-134	-125	-137	-137	-137.7	-138.5	-135.3	-122.3	-125.8
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	22.7	22.1	22.1	22.1	22.5	22.3	23.2	24.1	24	22.9	22.4	22.1	22.1
AirChange(/h)	0.9	0.7	0.7	0.7	0.7	0.8	1	1.5	1.4	0.8	0.7	0.7	0.7
Rel. Moisture(%)	37	**24.8**	**24.9**	**22.6**	**31.1**	**40.3**	**48**	**53.2**	**51.6**	**48.7**	**42.7**	**30.5**	**26.2**
Co2(ppm)	465.3	476.4	476.2	476.1	476	467.1	455.3	426.9	432	470.5	475.5	475.3	475.8
PAQ(-)	0.4	0.6	0.6	0.6	0.5	0.4	0.2	0	0.1	0.2	0.3	0.5	0.6
Hours > 21	8651	744	672	744	720	662	701	744	744	712	744	720	744
Hours > 26	112	0	0	0	0	0	15	53	39	5	0	0	0
Hours > 27	32	0	0	0	0	0	0	21	11	0	0	0	0
Hours < 19.9	0	0	0	0	0	0	0	0	0	0	0	0	0
FanPow	203.52	17.29	15.61	17.29	16.73	17.29	16.73	17.29	17.29	16.73	17.29	16.73	17.29
HtRec	3854.6	568.57	519.99	619.55	337.22	206.9	126	47.97	43.29	107.67	255.21	456.24	566.08
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Elderly | Traditional | Set Point: 20°C | Heat Recovery: 0.85 | Moisture Recovery: 0.86													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	954.12	189.89	165.31	201.22	37.14	0	0	0	0	0	34.69	127.6	198.25
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-782.36	-95.75	-87.43	-103	-68.49	-52.5	-42	-30.3	-29.69	-39.58	-58.07	-80.31	-95.22
qVenting	-354.49	0	0	0	-1.11	-20.8	-57	-140	-118.8	-16.46	-0.14	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	789.73	67.07	60.58	67.07	64.91	67.07	64.91	67.07	67.07	64.91	67.07	64.91	67.07
qEquipment	2653.22	226.22	203.49	224.6	218.37	225.4	217.6	226.2	224.6	217.56	226.22	217.56	225.41
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-2950.25	-354.2	-319.41	-372	-247.9	-210	-169	-108	-112	-171.88	-225.3	-300.27	-360.33
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-1348.51	-89.22	-81.78	-100.3	-106.2	-126	-137	-139	-139.5	-138.89	-115.1	-85.45	-89.7
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	21.7	20.1	20.1	20.2	21.5	22.3	23.2	24.1	24	22.9	21.7	20.4	20.1
AirChange(/h)	0.9	0.7	0.7	0.7	0.7	0.8	1	1.5	1.4	0.8	0.7	0.7	0.7
Rel. Moisture(%)	45.5	40.5	40.6	37.3	40.5	44.2	50.1	53.8	52.1	50.6	50	44.9	41.9
Co2(ppm)	465.7		476.9	476.7	476.5	467.1	455.4	427.2	432.3	470.6	475.8	475.9	476.5
PAQ(-)	0.3	0.5	0.5	0.5	0.4	0.3	0.2	0	0.1	0.2	0.3	0.4	0.5
Hours > 21	4820	12	15	50	477	662	701	744	744	712	597	88	18
Hours > 26	112	0	0	0	0	0	15	53	39	5	0	0	0
Hours > 27	31	0	0	0	0	0	0	20	11	0	0	0	0
Hours < 19.9	6	1	3	2	0	0	0	0	0	0	0	0	0
FanPow	101.76	8.64	7.81	8.64	8.36	8.64	8.36	8.64	8.64	8.36	8.64	8.36	8.64
HtRec	3778.52	548.71	501.14	591.07	340.26	210.7	129.2	50.06	45.63	111.33	258.98	445.73	545.67
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Elderly | Traditional | Set Point: 22°C | Heat Recovery: 0.85 | Moisture Recovery: 0.86													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	1552.05	295.61	258.66	292.68	96.06	0	0	0	0	0	82.59	223.66	302.8
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-831.27	-104.6	-95.34	-111.3	-72.87	-52.5	-42	-30.3	-29.69	-39.58	-61.23	-87.86	-103.97
qVenting	-355.07	0	0	0	-1.33	-20.8	-57	-140	-118.8	-16.46	-0.49	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	789.73	67.07	60.58	67.07	64.91	67.07	64.91	67.07	67.07	64.91	67.07	64.91	67.07
qEquipment	2653.22	226.22	203.49	224.6	218.37	225.4	217.6	226.2	224.6	217.56	226.22	217.56	225.41
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-3279.07	-413.8	-372.55	-427.1	-274.4	-210	-169	-108	-112	-171.88	-249.5	-351.84	-418.91
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-1568.14	-126.4	-114.07	-128.3	-134	-126	-137	-139	-139.5	-138.89	-135.3	-122.38	-126.9
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	22.7	22.1	22.1	22.1	22.5	22.3	23.2	24.1	24	22.9	22.4	22.1	22.1
AirChange(/h)	0.9	0.7	0.7	0.7	0.7	0.8	1	1.5	1.4	0.8	0.7	0.7	0.7
Rel. Moisture(%)	42.3	33.8	34	32	36.7	44.2	50.1	53.8	52.1	50.6	47.2	38.3	35.1
Co2(ppm)	465.3	476.3	476.1	476	476	467.1	455.4	427.2	432.3	470.6	475.4	475.2	475.7
PAQ(-)	0.3	0.5	0.5	0.5	0.4	0.3	0.2	0	0.1	0.2	0.3	0.4	0.4
Hours > 21	8651	744	672	744	720	662	701	744	744	712	744	720	744
Hours > 26	112	0	0	0	0	0	15	53	39	5	0	0	0
Hours > 27	31	0	0	0	0	0	0	20	11	0	0	0	0
Hours < 19.9	0	0	0	0	0	0	0	0	0	0	0	0	0
FanPow	101.76	8.64	7.81	8.64	8.36	8.64	8.36	8.64	8.64	8.36	8.64	8.36	8.64
HtRec	3895.09	572.7	523.62	621.74	341.35	210.7	129.2	50.06	45.63	111.33	259.52	460.21	569
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Elderly | HVV| Set Point: 20°C | Heat Recovery: 0.9 | Moisture Recovery: -													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-757.64	-95.72	-87.34	-102.6	-64.85	-48.9	-38.8	-28.6	-27.76	-35.33	-53.23	-79.33	-95.13
qVenting	-193.81	0	0	0	0	-6.42	-27.6	-85.6	-69.74	-4.44	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	796.97	67.76	61.13	67.63	65.53	67.69	65.46	67.76	67.63	65.46	67.76	65.46	67.69
qEquipment	2620.63	223.47	200.99	221.82	215.7	222.6	214.9	223.5	221.8	214.87	223.47	214.87	222.64
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-2771.66	-350.7	-315.69	-364.9	-221	-187	-150	-97.6	-98.09	-145.66	-193.2	-291.73	-356.21
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-733.04	99.25	81.67	95.66	-98.72	-164	-187	-204	-202.2	-179.24	-115.4	34.78	106.49
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	21.3	20.1	20.1	20.1	20.7	21.5	22.5	23.8	23.6	22	20.7	20.1	20.1
AirChange(/h)	1.2	1.1	1.1	1.1	1.1	1.1	1.3	1.6	1.5	1.1	1.1	1.1	1.1
Rel. Moisture for 20°c	38.8	26.7	26.8	24.2	33.4	41.2	49.2	54	52.4	50.5	46.1	33	28.2
Co2(ppm)	429.9	434	433.8	433.7	434.1	432.2	426.6	414.2	417.3	432.5	433.4	433.1	433.5
PAQ(-)	0.4	0.7	0.7	0.7	0.6	0.4	0.2	0	0.1	0.2	0.4	0.6	0.6
Hours > 21	3727	10	9	16	238	455	635	744	744	635	211	21	9
Hours > 26	73	0	0	0	0	0	7	38	28	0	0	0	0
Hours > 27	26	0	0	0	0	0	0	17	9	0	0	0	0
Hours < 19.9	42	0	0	1	2	31	4	0	0	3	0	0	1
FanPow	327.04	27.78	25.09	27.78	26.88	27.78	26.88	27.78	27.78	26.88	27.78	26.88	27.78
HtRec	5976.03	880.84	802.67	938.63	527.12	323.7	198.2	76.12	68.73	169.94	404.07	712.14	873.83
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	897.56	185.75	161.75	195.09	25.95	0	0	0	0	0	12.61	122.43	193.98
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Elderly | HVV | Set Point: 22°C | Heat Recovery: 0.9 | Moisture Recovery: -													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-814.79	-104.7	-95.43	-111.4	-71.67	-49	-38.8	-28.6	-27.76	-35.33	-60.14	-87.79	-104.08
qVenting	-193.83	0	0	0	0	-6.45	-27.6	-85.6	-69.74	-4.44	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	796.97	67.76	61.13	67.63	65.53	67.69	65.46	67.76	67.63	65.46	67.76	65.46	67.69
qEquipment	2620.63	223.47	200.99	221.82	215.7	222.6	214.9	223.5	221.8	214.87	223.47	214.87	222.64
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-3052.15	-403.9	-363.17	-414.1	-238.7	-186	-150	-97.6	-98.09	-145.66	-217.9	-331.34	-406.61
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-395.38	161.38	137.23	153.55	-74.21	-166	-187	-204	-202.2	-179.24	-83.83	82.85	165.84
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	22.3	22	22	22	22.2	21.5	22.5	23.8	23.6	22	22.2	22	22
AirChange(/h)	1.2	1.1	1.1	1.1	1.1	1.1	1.3	1.6	1.5	1.1	1.1	1.1	1.1
Rel. Moisture for 22°c	36.9	23.6	23.8	21.5	30.5	41.1	49.2	54	52.4	50.5	42.2	29.4	25
Co2(ppm)	429.6	433.5	433.2	433.1	433.7	432.2	426.6	414.2	417.3	432.5	433	432.6	433
PAQ(-)	0.4	0.6	0.6	0.6	0.5	0.4	0.2	0	0.1	0.2	0.3	0.5	0.6
Hours > 21	8318	744	672	744	720	472	635	744	744	635	744	720	744
Hours > 26	73	0	0	0	0	0	7	38	28	0	0	0	0
Hours > 27	26	0	0	0	0	0	0	17	9	0	0	0	0
Hours < 19.9	35	0	0	0	0	28	4	0	0	3	0	0	0
FanPow	327.04	27.78	25.09	27.78	26.88	27.78	26.88	27.78	27.78	26.88	27.78	26.88	27.78
HtRec	6504.46	964.66	878.42	1020	579.39	323.7	198.2	76.12	68.73	169.94	473.07	794.36	957.79
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	1339.44	264.87	232.14	270.1	71.93	0	0	0	0	0	49.1	181.67	269.63
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Elderly | HVV | Set Point: 20°C | Heat Recovery: 0.85 | Moisture Recovery: 0.86													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-757.03	-95.65	-87.27	-102.5	-64.81	-48.9	-38.8	-28.6	-27.7	-35.29	-53.21	-79.27	-95.06
qVenting	-187.74	0	0	0	0	-6.07	-26.8	-83.1	-67.58	-4.26	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	796.97	67.76	61.13	67.63	65.53	67.69	65.46	67.76	67.63	65.46	67.76	65.46	67.69
qEquipment	2620.63	223.47	200.99	221.82	215.7	222.6	214.9	223.5	221.8	214.87	223.47	214.87	222.64
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-2770.45	-350.7	-315.7	-364.9	-221	-187	-149	-97.2	-97.74	-145.45	-193.2	-291.73	-356.21
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-740.93	99.19	81.61	95.59	-98.78	-165	-188	-207	-204.7	-179.68	-115.4	34.72	106.42
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	21.3	20.1	20.1	20.1	20.7	21.5	22.5	23.8	23.6	22	20.7	20.1	20.1
AirChange(/h)	1.2	1.1	1.1	1.1	1.1	1.1	1.3	1.6	1.5	1.1	1.1	1.1	1.1
Rel. Moisture(%)	43.5	34.5	34.7	31.9	39	44.3	50.9	54.4	52.9	52.1	50.7	40.4	36.1
Co2(ppm)	429.9	434	433.7	433.6	434.1	432.3	426.7	414.7	417.7	432.6	433.4	433.1	433.5
PAQ(-)	0.4	0.6	0.6	0.6	0.5	0.4	0.2	0	0.1	0.2	0.3	0.5	0.6
Hours > 21	3727	10	9	16	238	455	635	744	744	635	211	21	9
Hours > 26	69	0	0	0	0	0	6	38	25	0	0	0	0
Hours > 27	25	0	0	0	0	0	0	16	9	0	0	0	0
Hours < 19.9	42	0	0	1	2	31	4	0	0	3	0	0	1
FanPow	163.52	13.89	12.54	13.89	13.44	13.89	13.44	13.89	13.89	13.44	13.89	13.44	13.89
HtRec	5804.56	838.06	764.31	893.83	525.25	329.8	203.4	79.5	72.51	175.74	405.52	684.97	831.72
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	1136.18	234.67	205.64	245.97	34.08	0.04	0.01	0	0	0.06	17.85	155.66	242.21
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Elderly | HVV | Set Point: 22°C | Heat Recovery: 0.85 | Moisture Recovery: 0.86													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-814.15	-104.7	-95.36	-111.3	-71.64	-49	-38.8	-28.6	-27.7	-35.29	-60.12	-87.73	-104.01
qVenting	-187.76	0	0	0	0	-6.09	-26.8	-83.1	-67.58	-4.26	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	796.97	67.76	61.13	67.63	65.53	67.69	65.46	67.76	67.63	65.46	67.76	65.46	67.69
qEquipment	2620.63	223.47	200.99	221.82	215.7	222.6	214.9	223.5	221.8	214.87	223.47	214.87	222.64
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-3050.94	-403.9	-363.17	-414.1	-238.7	-186	-149	-97.2	-97.74	-145.45	-217.9	-331.34	-406.61
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-403.3	161.31	137.17	153.48	-74.26	-166	-188	-207	-204.7	-179.68	-83.85	82.79	165.77
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	22.3	22	22	22	22.2	21.6	22.5	23.8	23.6	22	22.2	22	22
AirChange(/h)	1.2	1.1	1.1	1.1	1.1	1.1	1.3	1.6	1.5	1.1	1.1	1.1	1.1
Rel. Moisture(%)	41.1	30.4	30.6	28.2	35.1	44.2	50.9	54.4	52.9	52.1	46.5	35.9	31.8
Co2(ppm)	429.6	433.4	433.2	433.1	433.7	432.3	426.7	414.7	417.7	432.6	433	432.6	432.9
PAQ(-)	0.3	0.5	0.5	0.5	0.4	0.4	0.2	0	0.1	0.2	0.3	0.4	0.5
Hours > 21	8318	744	672	744	720	472	635	744	744	635	744	720	744
Hours > 26	69	0	0	0	0	0	6	38	25	0	0	0	0
Hours > 27	25	0	0	0	0	0	0	16	9	0	0	0	0
Hours < 19.9	35	0	0	0	0	28	4	0	0	3	0	0	0
FanPow	163.52	13.89	12.54	13.89	13.44	13.89	13.44	13.89	13.89	13.44	13.89	13.44	13.89
HtRec	6265.1	913.91	832.46	968.18	564.85	329.9	203.4	79.5	72.51	175.74	461.37	755.77	907.6
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	1645.82	321.74	283.6	327.99	92.77	0.01	0.01	0	0	0.06	67.45	226.3	325.91
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Working | Traditional | Set Point: 20°C | Heat Recovery: 0.92 | Moisture Recovery: -													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	1099.91	219.79	194.22	221.66	44.01	0	0	0	0	0	37.54	154.32	228.37
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-771.02	-95.69	-87.37	-102.62	-66.65	-49.42	-40.19	-31.84	-30.39	-36.12	-55.67	-79.89	-95.17
qVenting	-129.4	0	0	0	0	-3.88	-15.93	-60.9	-47.84	-0.85	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	555.33	48.08	42.55	46.39	45.96	47.23	45.11	48.08	46.39	45.11	48.08	45.11	47.23
qEquipment	2129.53	184.27	163.19	177.98	176.19	181.12	173.05	184.27	177.98	173.05	184.27	173.05	181.12
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-2768.58	-346.77	-312.15	-358.45	-209.95	-186.4	-160	-117.3	-112.4	-149.34	-186.05	-279.92	-349.86
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-1154.32	-65.65	-59.68	-67.38	-92.86	-105.4	-124.7	-146.8	-142.1	-116.19	-98.81	-68.61	-66.21
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	21.5	20.1	20.1	20.1	21.1	21.6	22.8	24.4	24.2	22.2	21.2	20.3	20.1
AirChange(/h)	0.8	0.7	0.7	0.7	0.7	0.8	0.8	1.1	1	0.7	0.7	0.7	0.7
Rel. Moisture(%)	39.5	28.3	28.3	25.7	34.1	42.5	49.6	52.9	51.7	51.3	46.1	34.2	29.8
Co2(ppm)	435.4	441.3	439.2	437.8	440.1	437.9	432.5	420.1	421.3	437.4	440.4	437.5	439.2
PAQ(-)	0.4	0.6	0.6	0.7	0.5	0.4	0.2	0	0	0.2	0.4	0.6	0.6
Hours > 21	4072	2	12	22	365	440	629	744	744	634	408	63	9
Hours > 26	97	0	0	0	0	0	4	51	42	0	0	0	0
Hours > 27	36	0	0	0	0	0	0	23	13	0	0	0	0
Hours < 19.9	91	0	0	0	0	57	19	0	0	14	0	1	0
FanPow	203.52	17.29	15.61	17.29	16.73	17.29	16.73	17.29	17.29	16.73	17.29	16.73	17.29
HtRec	3853.47	568.56	519.94	618.89	337.22	206.85	125.96	47.97	43.29	107.67	255.21	456.23	565.7
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Working | Traditional | Set Point: 22°C | Heat Recovery: 0.92 | Moisture Recovery: -													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	1850	348.65	309.52	347.02	119.45	0	0	0	0	0	113.03	269.62	355.5
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-823.53	-104.59	-95.33	-111.27	-72.08	-49.38	-40.15	-31.82	-30.37	-36.08	-60.69	-87.82	-103.95
qVenting	-129	0	0	0	0	-3.86	-15.85	-60.73	-47.72	-0.83	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	555.33	48.08	42.55	46.39	45.96	47.23	45.11	48.08	46.39	45.11	48.08	45.11	47.23
qEquipment	2129.53	184.27	163.19	177.98	176.19	181.12	173.05	184.27	177.98	173.05	184.27	173.05	181.12
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-3128.35	-406.79	-365.89	-417.14	-244.13	-186.8	-160.4	-117.6	-112.7	-149.63	-223.7	-334.34	-409.4
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-1505.32	-125.59	-113.28	-125.4	-128.7	-105.1	-124.5	-146.7	-141.9	-115.95	-131.63	-121.56	-125.01
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	22.5	22	22	22	22.3	21.6	22.8	24.4	24.2	22.2	22.3	22.1	22
AirChange(/h)	0.8	0.7	0.7	0.7	0.7	0.8	0.8	1.1	1	0.7	0.7	0.7	0.7
Rel. Moisture(%)	37.8	25.2	25.2	22.9	31.8	42.5	49.7	52.9	51.7	51.4	43.3	30.8	26.5
Co2(ppm)	435.1	440.7	438.6	437.2	439.8	438	432.5	420.1	421.3	437.4	440	437	438.7
PAQ(-)	0.4	0.6	0.6	0.6	0.5	0.4	0.2	0	0	0.2	0.3	0.5	0.6
Hours > 21	8272	744	672	744	720	438	626	744	744	633	743	720	744
Hours > 26	97	0	0	0	0	0	4	51	42	0	0	0	0
Hours > 27	36	0	0	0	0	0	0	23	13	0	0	0	0
Hours < 19.9	94	0	0	0	0	59	21	0	0	14	0	0	0
FanPow	203.52	17.29	15.61	17.29	16.73	17.29	16.73	17.29	17.29	16.73	17.29	16.73	17.29
HtRec	3854.6	568.57	519.99	619.55	337.22	206.85	125.96	47.97	43.29	107.67	255.21	456.24	566.08
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Working | Traditional | Set Point: 20°C | Heat Recovery: 0.85 | Moisture Recovery: 0.86													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	1223.18	244.55	217.61	254.07	45.86	0	0	0	0	0	38.23	169.76	253.1
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-769.57	-95.52	-87.21	-102.44	-66.53	-49.32	-40.1	-31.75	-30.31	-36.04	-55.58	-79.76	-95.01
qVenting	-126.03	0	0	0	0	-3.7	-15.44	-59.5	-46.64	-0.75	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	555.33	48.08	42.55	46.39	45.96	47.23	45.11	48.08	46.39	45.11	48.08	45.11	47.23
qEquipment	2129.53	184.27	163.19	177.98	176.19	181.12	173.05	184.27	177.98	173.05	184.27	173.05	181.12
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-2779.31	-348.78	-313.91	-360.47	-210.5	-186.7	-160.1	-117.1	-112.3	-149.41	-186.58	-281.46	-351.92
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-1271.69	-88.58	-81.47	-97.95	-94.28	-105.3	-125.2	-148.4	-143.5	-116.3	-99.05	-82.64	-89.04
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	21.5	20.1	20.1	20.1	21.1	21.6	22.8	24.4	24.2	22.2	21.2	20.3	20.1
AirChange(/h)	0.8	0.7	0.7	0.7	0.7	0.8	0.8	1	1	0.7	0.7	0.7	0.7
Rel. Moisture(%)	47.6	42.4	42.1	38.9	43.4	48.3	52.8	53.7	52.5	54.2	53.4	46.5	43.4
Co2(ppm)	435.4	441.1	439.1	437.7	440.1	437.9	432.5	420.3	421.7	437.4	440.3	437.4	439.1
PAQ(-)	0.3	0.5	0.5	0.5	0.4	0.3	0.1	0	0	0.2	0.3	0.4	0.5
Hours > 21	4056	2	12	21	361	438	627	744	744	633	407	59	8
Hours > 26	95	0	0	0	0	0	3	50	42	0	0	0	0
Hours > 27	35	0	0	0	0	0	0	23	12	0	0	0	0
Hours < 19.9	96	0	1	0	0	59	22	0	0	14	0	0	0
FanPow	101.76	8.64	7.81	8.64	8.36	8.64	8.36	8.64	8.64	8.36	8.64	8.36	8.64
HtRec	3772.29	547.81	500	589.54	339.38	210.66	129.17	50.06	45.63	111.25	258.89	444.96	544.94
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Working | Traditional | Set Point: 22°C | Heat Recovery: 0.85 | Moisture Recovery: 0.86													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	1865.14	348.58	309.55	348.62	119.33	0	0	0	0	0	112.97	269.61	356.48
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-822.64	-104.48	-95.23	-111.14	-72.03	-49.33	-40.1	-31.75	-30.31	-36.04	-60.65	-87.74	-103.84
qVenting	-126.03	0	0	0	0	-3.7	-15.44	-59.5	-46.64	-0.75	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	555.33	48.08	42.55	46.39	45.96	47.23	45.11	48.08	46.39	45.11	48.08	45.11	47.23
qEquipment	2129.53	184.27	163.19	177.98	176.19	181.12	173.05	184.27	177.98	173.05	184.27	173.05	181.12
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-3126.95	-406.79	-365.89	-417.11	-244.11	-186.7	-160.1	-117.1	-112.3	-149.41	-223.73	-334.35	-409.36
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-1512.93	-125.62	-113.41	-127.15	-128.65	-105.4	-125.2	-148.4	-143.5	-116.3	-131.57	-121.63	-126.15
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	22.5	22	22	22	22.3	21.6	22.8	24.4	24.2	22.2	22.3	22.1	22
AirChange(/h)	0.8	0.7	0.7	0.7	0.7	0.8	0.8	1	1	0.7	0.7	0.7	0.7
Rel. Moisture(%)	43.9	35.2	35.1	33.1	38.3	48.3	52.8	53.7	52.5	54.2	48.5	39.2	36.2
Co2(ppm)	435.1	440.6	438.5	437.1	439.7	437.9	432.5	420.3	421.7	437.4	440	436.9	438.6
PAQ(-)	0.3	0.4	0.4	0.5	0.4	0.3	0.1	0	0	0.2	0.2	0.4	0.4
Hours > 21	8273	744	672	744	720	438	627	744	744	633	743	720	744
Hours > 26	95	0	0	0	0	0	3	50	42	0	0	0	0
Hours > 27	35	0	0	0	0	0	0	23	12	0	0	0	0
Hours < 19.9	95	0	0	0	0	59	22	0	0	14	0	0	0
FanPow	101.76	8.64	7.81	8.64	8.36	8.64	8.36	8.64	8.64	8.36	8.64	8.36	8.64
HtRec	3894.81	572.7	523.62	621.72	341.35	210.66	129.17	50.06	45.63	111.25	259.52	460.22	568.92
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Working | HVV| Set Point: 20°C | Heat Recovery: 0.9 | Moisture Recovery: -													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-745.49	-95.61	-87.25	-102.38	-63.38	-46.83	-36.81	-28.32	-26.73	-32.23	-51.75	-79.16	-95.04
qVenting	-63.81	0	0	0	0	-0.76	-5.15	-31.96	-25.84	-0.11	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	545.79	47.17	41.83	45.66	45.14	46.42	44.38	47.17	45.66	44.38	47.17	44.38	46.42
qEquipment	2142.38	185.38	164.17	179.05	177.26	182.22	174.09	185.38	179.05	174.09	185.38	174.09	182.22
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-2693.11	-350.01	-314.91	-363.09	-210.41	-173.5	-139	-96.08	-88.89	-127.64	-183.92	-290.37	-355.24
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-224.3	157.1	136.92	158.34	-51.92	-124.2	-160.2	-200.6	-191.6	-142.84	-67.52	95.11	167.13
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	21.1	20	20	20.1	20.4	21.5	22.3	23.7	23.4	21.8	20.4	20.1	20
AirChange(/h)	1.2	1.1	1.1	1.1	1.1	1.1	1.2	1.3	1.3	1.1	1.1	1.1	1.1
Rel. Moisture(%)	39.7	27	27.1	24.5	34.4	42.9	50.9	54.6	53.4	52.9	47.3	33.3	28.5
Co2(ppm)	406.1	408.5	407.3	406.5	408	407.1	405.4	401.3	401.2	406.6	408.1	406.3	407.3
PAQ(-)	0.4	0.7	0.7	0.7	0.6	0.4	0.2	0	0.1	0.3	0.4	0.6	0.6
Hours > 21	2914	0	2	7	99	319	507	744	742	400	78	16	0
Hours > 26	73	0	0	0	0	0	1	44	28	0	0	0	0
Hours > 27	25	0	0	0	0	0	0	19	6	0	0	0	0
Hours < 19.9	0	0	0	0	0	215	54	0	0	0	0	0	0
FanPow	327.04	27.78	25.09	27.78	26.88	27.78	26.88	27.78	27.78	26.88	27.78	26.88	27.78
HtRec	6030.77	882.21	804.21	943.53	535.99	331.56	201.12	76.12	68.73	172.22	419.69	719.18	876.19
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	1209.98	241.26	214.69	250.57	48.54	0	0	0	0	0	29.41	174.08	251.43
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Working | HVV | Set Point: 22°C | Heat Recovery: 0.9 | Moisture Recovery: -													
	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-819.41	-104.66	-95.38	-111.3	-71.25	-52.64	-40.03	-28.44	-27.13	-36.91	-59.9	-87.73	-104.02
qVenting	-65.25	0	0	0	0	-1.31	-5.17	-32.06	-26.04	-0.67	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	545.79	47.17	41.83	45.66	45.14	46.42	44.38	47.17	45.66	44.38	47.17	44.38	46.42
qEquipment	2142.38	185.38	164.17	179.05	177.26	182.22	174.09	185.38	179.05	174.09	185.38	174.09	182.22
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-3078	-403.31	-362.68	-413.41	-235	-209.1	-156.8	-96.76	-92.36	-158.45	-213.44	-330.68	-405.94
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	235.93	219.45	192.83	217.57	-19.46	-82.26	-139.1	-199.7	-187.5	-106.79	-29.85	143.99	226.82
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	22.4	22	22	22	22.1	21.5	22.3	23.7	23.4	21.8	22.1	22	22
AirChange(/h)	1.2	1.1	1.1	1.1	1.1	1.1	1.2	1.3	1.3	1.1	1.1	1.1	1.1
Rel. Moisture(%)	37	23.9	24	21.7	31	39.3	48.8	54.5	53.1	49.8	42.6	29.6	25.3
Co2(ppm)	405.9	408.2	406.9	406.1	407.7	406.8	405.3	401.3	401.2	406.3	407.8	406	406.9
PAQ(-)	0.4	0.6	0.6	0.6	0.5	0.4	0.2	0	0.1	0.2	0.3	0.5	0.6
Hours > 21	8760	744	672	744	720	744	720	744	744	720	744	720	744
Hours > 26	73	0	0	0	0	0	1	44	28	0	0	0	0
Hours > 27	25	0	0	0	0	0	0	19	6	0	0	0	0
Hours < 19.9	0	0	0	0	0	211	50	0	0	0	0	0	0
FanPow	327.04	27.78	25.09	27.78	26.88	27.78	26.88	27.78	27.78	26.88	27.78	26.88	27.78
HtRec	6770.14	966.8	880.62	1026.45	607.15	395.79	237.19	78.22	75.69	236.99	502.99	801.34	960.92
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	1663.13	320.69	285.59	327.64	95.02	0	0	0	0	0	71.04	235.72	327.43
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Working | HVV | Set Point: 20°C | Heat Recovery: 0.85 | Moisture Recovery: 0.86

	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-744.5	-95.53	-87.18	-102.3	-63.32	-46.76	-36.72	-28.17	-26.59	-32.16	-51.7	-79.1	-94.96
qVenting	-60.84	0	0	0	0	-0.63	-4.78	-30.62	-24.8	-0.02	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	545.79	47.17	41.83	45.66	45.14	46.42	44.38	47.17	45.66	44.38	47.17	44.38	46.42
qEquipment	2142.38	185.38	164.17	179.05	177.26	182.22	174.09	185.38	179.05	174.09	185.38	174.09	182.22
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-2702.16	-351.71	-316.49	-364.93	-211.19	-173.9	-139	-95.57	-88.34	-127.74	-184.6	-291.66	-357.01
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	-219.22	158.72	138.43	160.09	-51.2	-124	-160.7	-202.6	-193.3	-142.9	-66.88	96.34	168.83
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	21	20	20	20.1	20.4	21.1	22	23.7	23.4	21.3	20.4	20.1	20
AirChange(/h)	1.2	1.1	1.1	1.1	1.1	1.1	1.2	1.3	1.3	1.1	1.1	1.1	1.1
Rel. Moisture(%)	45.3	36	35.9	33.1	41.5	47.8	53.6	55.3	54.1	55.4	53.5	41.7	37.3
Co2(ppm)	406.2	408.5	407.2	406.4	408	407.1	405.5	401.6	401.4	406.7	408.1	406.3	407.3
PAQ(-)	0.4	0.6	0.6	0.6	0.5	0.4	0.2	0	0.1	0.2	0.3	0.5	0.5
Hours > 21	2903	0	2	7	95	319	504	744	741	397	78	16	0
Hours > 26	72	0	0	0	0	0	1	43	28	0	0	0	0
Hours > 27	25	0	0	0	0	0	0	19	6	0	0	0	0
Hours < 19.9	315	0	0	0	0	225	55	0	0	35	0	0	0
FanPow	163.52	13.89	12.54	13.89	13.44	13.89	13.44	13.89	13.89	13.44	13.89	13.44	13.89
HtRec	5821.67	837.55	763.65	893.89	527.04	333.39	204.85	79.49	72.5	176.98	414.01	686.78	831.54
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	1488.01	293.61	262.26	307.98	64.32	0	0	0	0	0	42.23	213.73	303.88
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Working | HVV | Set Point: 22°C | Heat Recovery: 0.85 | Moisture Recovery: 0.86

	Sum/Mean	January	February	March	April	May	June	July	August	September	October	November	December
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-818.51	-104.58	-95.31	-111.22	-71.2	-52.59	-39.96	-28.3	-27	-36.87	-59.86	-87.66	-103.95
qVenting	-62.34	0	0	0	0	-1.2	-4.81	-30.73	-25	-0.6	0	0	0
qSunRad	499.55	6.37	14.44	34.12	62.22	74.91	82.1	84.55	66.62	40.04	21.34	7.94	4.91
qPeople	545.79	47.17	41.83	45.66	45.14	46.42	44.38	47.17	45.66	44.38	47.17	44.38	46.42
qEquipment	2142.38	185.38	164.17	179.05	177.26	182.22	174.09	185.38	179.05	174.09	185.38	174.09	182.22
qLighting	539	49.6	44.8	48.3	41.1	41.8	40.6	39.9	41.7	44.3	49.3	48	49.6
qTransmission	-3091.22	-405.71	-364.84	-415.78	-235.98	-209.8	-157	-96.32	-91.92	-158.82	-214.32	-332.42	-408.31
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	245.35	221.76	194.91	219.86	-18.53	-81.73	-139.4	-201.7	-189.1	-106.52	-29.01	145.67	229.11
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mean(°C)	8.1	0.7	0.4	-0.7	7.1	11.5	14.2	17.8	17.9	14.5	9.8	3.4	0.7
tOp mean(°C)	22.4	22	22	22	22.1	21.4	22.4	23.7	23.5	22.3	22.1	22	22
AirChange(/h)	1.2	1.1	1.1	1.1	1.1	1.1	1.2	1.3	1.3	1.1	1.1	1.1	1.1
Rel. Moisture(%)	42.1	31.7	31.6	29.3	36.9	43.5	51.4	55.3	53.9	52.9	48.3	36.9	32.9
Co2(ppm)	405.9	408.1	406.9	406.1	407.6	406.8	405.3	401.6	401.3	406.2	407.8	405.9	406.9
PAQ(-)	0.3	0.5	0.5	0.5	0.4	0.3	0.2	0	0.1	0.2	0.3	0.4	0.5
Hours > 21	8760	744	672	744	720	744	720	744	744	720	744	720	744
Hours > 26	72	0	0	0	0	0	1	43	28	0	0	0	0
Hours > 27	25	0	0	0	0	0	0	19	6	0	0	0	0
Hours < 19.9	0	0	0	0	0	225	55	0	0	31	0	0	0
FanPow	163.52	13.89	12.54	13.89	13.44	13.89	13.44	13.89	13.89	13.44	13.89	13.44	13.89
HtRec	6472.58	914.75	833.23	971.69	585.22	385.87	234.82	81.56	78.89	233.48	484.33	759.68	909.04
ClRec	0	0	0	0	0	0	0	0	0	0	0	0	0
HtCoil	2006.48	381.15	340.57	390.71	124.09	0	0	0	0	0	97.12	285.12	387.72
ClCoil	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidif	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorHeat	0	0	0	0	0	0	0	0	0	0	0	0	0
FloorCool	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPumpPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCoolingPow	0	0	0	0	0	0	0	0	0	0	0	0	0
CentHeatPump	0	0	0	0	0	0	0	0	0	0	0	0	0
CentCooling	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix E

Appendix E

This appendix include data related do LCA.

AIA LU-VE

AIACalc

LU-VE Sweden AB		Project Ref.	final
Tel +46 454 334 00		Item Ref.	d
info@aia.se		Date	1/1/2024
		Prgver.	2304.1 11/30/2023

	Air Data	**Fluid Data**	**Remark**
Flow	0.06 m³/s (202 m³/h)	0.02 l/s	
Front Velocity	0.3 m/s		
Inlet Temp.	18.0 °C	40.0 °C	
Outlet Temp.	35.3 °C	25.0 °C	
Air Pressure Drop	1 Pa		
Pressure Drop		1 kPa	
Fluid Velocity		0.18 m/s	
Fluid		[tf=0 °C]	Pure Water

Type of Finned Coil	35 x 30
Total Capacity	1.18 kW
Fins	AL 3 mm / 0.18 mm
Tubes	CU Ø12 / 0.35 mm
Fin Type	Industrial Fins
Fin Length	680 mm
Fin Depth	121 mm
Front Area	245 mm x 680 mm
No. Tubes Wide	7
No. Rows Deep	4
No. of Circuits	1
Tube Volume	2.3 liters
Header Volume	0.0 l
Internal volume	2.3 l
Surface Area	12.6 m² / +0.0 % Surface Margin
Tube connection	1 x 12 mm - 1 x 12 mm
Allowable Pressure, Ps	10 bar

Figure E.1: Manifold Calculation from AIACalc Software

Fin Block		
Fin Block		
Model	35 x 30.31	
No. Tubes Wide	7	
Fin Height	245	mm
Fin Length	680	mm
No. Rows Deep	4	
No. of Circuits	1	
Fins	AL 3 mm / 0.18	mm
Tubes	CU Ø12 / 0.35	mm
Air Data		
Flow	0.06	m^3/s
Pressure Drop	1	Pa
Air density	1.213	kg/m^3
Fluid Data		
Fluid	Pure Water	
Mean Temperature	32.5	°C
Density	994.8	kg/m^3
Specific Heat	4178.4	J/kg/K
Thermal Conductivity	0.620	W/m/K
Viscosity	0.757	mPa.s
Tube Data		
Fluid Velocity	0.18	m/s
Reynolds number	2709	
Hi Coefficient	1003.5	$W/m^2/K$
Pressure Drop	1.36	kPa
Headers		
Overall		
Total Pressure Drop	1.36	kPa

Figure E.2: Manifold Calculation from AIACalc Software

Description	Name	Input	Calculated amount			Mass [kg]
Sum	Element					185.54
Group	Space heating					104.33
Subgroup	Radiators					90.33
Element	Radaitor					90.33
Construction	C33 450 1400	1.20	m²			62.76
Products	Radiator	52.30	kg/m²	62.76	kg	62.76
Construction	C22 450 1400	0.65	m²			22.62
Products	Radiator	34.80	kg/m²	22.62	kg	22.62
Construction	FLO0505	0.15	m²			4.95
Products	Radiator	33.00	kg/m²	4.95	kg	4.95
Subgroup	Heat distribution					14.00
Element	Pipes					14.00
Construction	Distribution pipes	40.00	m			14.00
Products	PE coated copper plumbing pipes	0.35	kg/m	14.00	kg	14.00
Group	Ventilation and cooling					81.21
Subgroup	Ventilation unit					28.00
Element	Ventilation					28.00
Construction	Ventilation Unit	1.00	stk.			28.00
Products	ventilation unit	28.00	kg/stk.	1.00	stk.	28.00
Subgroup	Ductwork					53.21
Element	ducts					53.21
Construction	Ventilation ducts Ø125	4.20	m			5.92
Products	Air ventilation duct (zinc coated steel plate)	1.41	kg/m	5.92	kg	5.92
Construction	Ventilation ducts Ø100	8.70	m			9.92
Products	Air ventilation duct (zinc coated steel plate)	1.14	kg/m	9.92	kg	9.92
Construction	Ventilation ducts Ø160	18.50	m			37.37
Products	Air ventilation duct (zinc coated steel plate)	2.02	kg/m	37.37	kg	37.37

Figure E.3: LCA input table for Traditional System

Description	Name	Input	Calculated amount			Mass [kg]
Sum	Element					83.31
Group	Space heating					42.05
Subgroup	Heat distribution					42.05
Element	manifold					42.05
Construction	27 - G3 filter	0.29	m²			0.97
Products	syntetic fiber	3.36	kg/m²	0.97	kg	0.97
Construction	54 - insulation	0.32	m²			0.22
Products	EPS insulation for walls and roofs W / D 035	0.03	m³/m²	0.01	m³	0.22
Construction	59 - rolskal	0.54	m²			0.18
Products	Mineral wool (partition walls insulation) (Clone)	0.01	m³/m²	0.01	m³	0.18
Construction	1 - body	0.81	m²			6.70
Products	Steel sheet (0.3-30mm)	8.27	kg/m²	6.70	kg	6.70
Construction	2 and 3 - air stop	0.06	m²			0.50
Products	Steel sheet (0.3-30mm)	8.27	kg/m²	0.50	kg	0.50
Construction	5 - splitter	0.24	m²			1.98
Products	Steel sheet (0.3-30mm)	8.27	kg/m²	1.98	kg	1.98
Construction	6 - splitter	0.05	m²			0.42
Products	Steel sheet (0.3-30mm)	8.27	kg/m²	0.42	kg	0.42
Construction	20 - cover	0.34	m²			2.84
Products	Steel sheet (0.3-30mm)	8.27	kg/m²	2.84	kg	2.84
Construction	21 - cover	0.36	m²			2.97
Products	Steel sheet (0.3-30mm)	8.27	kg/m²	2.97	kg	2.97
Construction	26 - copper tube Ø12 mm, t=0,35 mm.	21.50	m			2.58
Products	Bare copper plumbing pipes (Clone)	0.12	kg/m	2.58	kg	2.58
Construction	screws	20.00	stk.			0.10
Products	Steel screws	0.01	kg/stk.	0.10	kg	0.10
Construction	Ventilation ducts Ø125	0.58	m			0.78
Products	Air ventilation duct (zinc coated steel plate)	1.34	kg/m	0.78	kg	0.78
Construction	23 - damper	0.25	m			2.22
Products	Air ventilation duct (zinc coated steel plate)	9.05	kg/m	2.22	kg	2.22
Construction	26 - aluminum fins	0.17	m²			19.58
Products	Aluminium sheet (Clone)	115.18	kg/m²	19.58	kg	19.58
Group	Ventilation and cooling					41.26
Subgroup	Ventilation unit					28.00
Element	Ventilation					28.00
Construction	Ventilation Unit	1.00	stk.			28.00
Products	ventilation unit	28.00	kg/stk.	1.00	stk.	28.00
Subgroup	Ductwork					13.26
Element	ducts					13.26
Construction	Ventilation ducts Ø100	2.40	m			2.74
Products	Air ventilation duct (zinc coated steel plate)	1.14	kg/m	2.74	kg	2.74
Construction	Ventilation ducts Ø125	2.00	m			2.68
Products	Air ventilation duct (zinc coated steel plate)	1.34	kg/m	2.68	kg	2.68
Construction	Ventilation ducts Ø160	1.50	m			2.12
Products	Air ventilation duct (zinc coated steel plate)	1.41	kg/m	2.12	kg	2.12
Construction	Ventilation ducts Ø80	6.30	m			5.73
Products	Air ventilation duct (zinc coated steel plate)	0.91	kg/m	5.73	kg	5.73

Figure E.4: LCA input table for HVV System

Parts list						
POS	Piec.	Description	Drawing no.	Item no.	Carbon	Weight
1	1	Body 6, 800 x 490 x 425	19-111409		8,7 kg	6,689 kg
2	1	Air-stop 6, 1	18-107513		0,28 kg	0,216 kg
3	1	Air-stop 6, 2	18-107468		0,28 kg	0,213 kg
5	1	Splitter 1.1, 6	18-107434		2,57 kg	1,978 kg
6	1	Splitter 2.1, 6	18-107443		0,54 kg	0,421 kg
20	1	Side for connection 6xØ125, Assembly	18-107432			2,848 kg
21	1	Side for connection 6, Ø250, assembly	18-107431			2,969 kg
23	6	Temperatur damper, full heat	19-107864			2,219 kg
24	2	Temperatur damper, full fresh air	19-107954			2,219 kg
25	2	Temperatur damper, heat 50%, fresh air 50%	19-107955			2,219 kg
26	1	4 x 245x35 Battry, 0,68 M	18-107456			21,769 kg
27	1	AEC 423x680, G3	18-107437			0,967 kg
28	1	Splitter 2.2, 6 and sealing	18-107448			1,723 kg
31	6	MF-125	136402	231108		0,234 kg
250	6	Screw, M4x10 Din7985, Bossard 2724	20102037	850839		0,000 kg
52	4	WasherDIN 9021-BN 1075-M3(3,2x9x0,8)N				0,000 kg
53	10	ø3,5 x 16 DIN7981 Self tapping screw	624165	492371	Not Found	0,000 kg
54	2	Airfelt TK	18-107436		0,64 kg	0,213 kg
55	1	Sealing cover, 6,2	19-107638	646754	Not Found	0,001 kg
56	1	Sealing splitter 2x8 mm, compress	18-107438	646753	Not Found	0,008 kg
59	2	Rørskål, Ø12 thk 13mm, l 215	19-107569		0,03 kg	0,010 kg
62	1	Sealing cover, 6x8, 6,1 ,compressed	18-107445	646754	Not Found	0,009 kg
63	4	12mm pipe rubber sleeves	663410	663410	Not Found	0,002 kg
64	4	Magnet ø15x2.	A-98380	645813	Not Found	0,003 kg
100		Parts for "Cover Insulatet" incl. Quicklock				
129	1	Cover assembly, Insulated, 802x492	19-111396			4,668 kg
133	14	Blind rivet 3,2x8 Art:6700012 Grip range 0,5-5,5	622130	492351	Not Found	0,000 kg
200		Parts for "Cover without Insulatet"				
207	1	Cover, 804x494	19-107628		4,68 kg	3,599 kg
233	14	Blind rivet 3,2x8 Art:6700012 Grip range 0,5-5,5	622130	492351	Not Found	0,000 kg
251	6	Rivet nut M4 (M4x6x10)	133700	853440		0,000 kg
57	4	Spænbeslag 78x30 mm, elgalvanicert	19-111373			0,018 kg

Figure E.5: List of materials used for HVV manifold

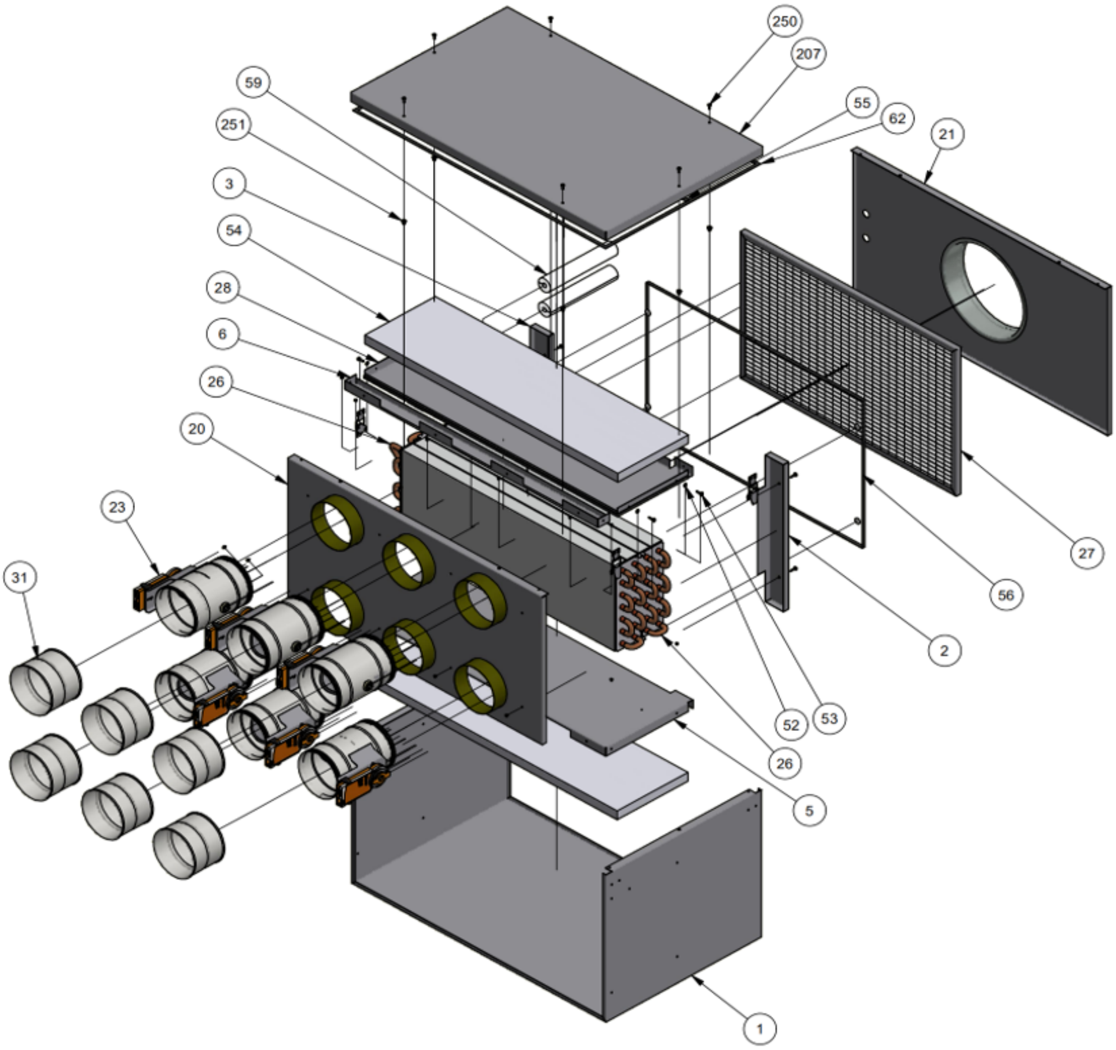


Figure E.6: Drawing of elements used for HVV manifold

			Area	weight	length	weight
			m2	kg	m	kg
1	1	Body 6. 800 x 490 x 425	0.8085	6.689		
			1	8.27335		
2	1	Air-stop 6. 1	0.03	0.216		
			1	8.27335		
3	1	Air-stop 6. 2	0.03	0.216		
			1	8.27335		
5	1	Splitter 1.1. 6	0.24	1.978		
			1	8.27335		
6	1	Splitter 2.1. 6	0.051	0.421		
			1	8.27335		
20	1	Side for connection 6x125. Assembly	0.344	2.848		
			1	8.27335		
21	1	Side for connection 6. 250. assembly	0.359	2.969		
			1	8.27335		
23	6	Temperatur damper. full heat	0.245	2.219		
			1	9.05714		
26	**1**	**4 x 245x35 Battry. 0.68 M**		21.769		
		cooper tube			21.5	2.58
					1	0.12
		aluminum fin	0.1666	19.189		
			1	115.18		
27	1	AEC 423x680. G3	0.28764	0.967		
			1	3.36184		
28	1	Splitter 2.2. 6 and sealing	0.208	1.723		
			1	8.27335		
31	6	MF-125			0.097	0.13
					1	1.340206
250	6	Screw. M4x10 Din7985. Bossard 2724				
52	4	WasherDIN 9021-BN 1075-M3(3.2x9x0.8)N				
53	10	¡3.5 x 16 DIN7981 Self tapping screw				
54	2	Airfelt TK	0.16	0.213		
			1	1.33125		
55	1	Sealing cover. 6.2	0.00012087	0.001		
			1	8.27335		
56	1	Sealing splitter 2x8 mm. compress	0.021	0.008		
			1	0.3876		
59	2	Rorskal. Ø12 thk 13mm. l 215	0.260623	0.01		
			1	0.03837		
62	1	Sealing cover. 6x8. 6.1 .compressed	0.02064	0.009		
			1	0.43605		
63	4	12mm pipe rubber sleeves				
64	4	Magnet ¡15x2.				
[illegible]		[illegible]				
129	1	Cover assembly. Insulated. 802x492 (just insulation)	0.394584	1.069		
			1	2.70918		
133	14	Blind rivet 3.2x8 Art:6700012 Grip range 0.5-5.5				
[illegible]		[illegible]				
207	1	Cover. 804x494	0.397176	3.599		
			1	8.27335		

Figure E.7: List of materials with calculated weight per unit

4.A. LCA results

Core Environmental impact per one ProAir PA600LI / ProAir PA600PLI Heat Recovery Ventilation Unit

PARAMETER	UNIT	A1	A2	A3	TOTAL A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
GWP-total	[kg CO_2 eq.]	2.44E+02	9.10E-01	3.36E+01	2.79E+02	2.26E+00	7.40E+02	0.00E+00	0.00E+00	0.00E+00	4.12E+01	0.00E+00	3.11E+03	0.00E+00	0.00E+00	3.00E-01	1.03E+01	2.86E+00	-2.59E+02
GWP-fossil	[kg CO_2 eq.]	2.42E+02	9.09E-01	2.17E+01	2.65E+02	2.26E+00	7.45E+02	0.00E+00	0.00E+00	0.00E+00	4.14E+01	0.00E+00	3.07E+03	0.00E+00	0.00E+00	3.00E-01	1.04E+01	2.86E+00	-2.57E+02
GWP-biogenic	[kg CO_2 eq.]	1.23E+00	5.37E-04	1.20E+01	1.32E+01	1.03E-03	-5.17E+00	0.00E+00	0.00E+00	0.00E+00	-2.81E-01	0.00E+00	3.29E+01	0.00E+00	0.00E+00	1.49E-04	-7.25E-02	2.62E-03	-9.88E-01
GWP-luluc	[kg CO_2 eq.]	1.03E+00	3.41E-04	1.85E-03	1.04E+00	1.26E-03	7.51E-01	0.00E+00	0.00E+00	0.00E+00	6.35E-02	0.00E+00	2.88E+00	0.00E+00	0.00E+00	1.30E-04	1.86E-02	1.17E-04	-1.27E+00
ODP	[kg CFC-11 eq.]	1.99E-05	2.04E-07	2.29E-06	2.24E-05	4.84E-07	2.32E-04	0.00E+00	0.00E+00	0.00E+00	2.59E-06	0.00E+00	1.43E-04	0.00E+00	0.00E+00	6.64E-08	4.53E-07	6.90E-08	-1.54E-05
AP	[mol H+ eq.]	2.01E+00	4.91E-03	3.83E-02	2.05E+00	6.62E-03	4.21E+00	0.00E+00	0.00E+00	0.00E+00	4.52E-01	0.00E+00	1.35E+01	0.00E+00	0.00E+00	8.61E-04	5.86E-02	2.01E-03	-1.29E+00
EP-freshwater[1]	[kg P eq.]	2.69E-02	8.16E-06	1.53E-04	2.71E-02	2.54E-05	2.84E-02	0.00E+00	0.00E+00	0.00E+00	3.64E-03	0.00E+00	8.05E-02	0.00E+00	0.00E+00	2.75E-06	6.00E-04	6.51E-06	-1.36E-02
EP-marine	[kg N eq.]	2.61E-01	9.67E-04	2.51E-02	2.88E-01	1.18E-03	1.06E+00	0.00E+00	0.00E+00	0.00E+00	4.34E-02	0.00E+00	1.92E+00	0.00E+00	0.00E+00	1.63E-04	9.25E-03	6.03E-03	-2.10E-01
EP-terrestrial	[mol N eq.]	3.05E+00	1.09E-02	1.00E-01	3.16E+00	1.33E-02	1.16E+01	0.00E+00	0.00E+00	0.00E+00	5.36E-01	0.00E+00	2.26E+01	0.00E+00	0.00E+00	1.83E-03	1.11E-01	7.50E-03	-2.39E+00
POCP	[kg NMVOC eq.]	9.08E-01	3.47E-03	3.34E-02	9.45E-01	5.12E-03	3.46E+00	0.00E+00	0.00E+00	0.00E+00	1.71E-01	0.00E+00	5.87E+00	0.00E+00	0.00E+00	6.99E-04	2.84E-02	2.71E-03	-7.45E-01
ADP-minerals&metals[2]	[kg Sb eq.]	4.47E-02	2.23E-05	1.58E-04	4.49E-02	1.11E-04	1.18E-02	0.00E+00	0.00E+00	0.00E+00	5.21E-03	0.00E+00	1.26E-02	0.00E+00	0.00E+00	1.08E-05	3.17E-04	2.42E-06	-1.72E-03
ADP-fossils[2]	[MJ] ncv	3.58E+03	1.37E+01	3.45E+02	3.94E+03	3.35E+01	1.44E+04	0.00E+00	0.00E+00	0.00E+00	8.14E+02	0.00E+00	4.42E+04	0.00E+00	0.00E+00	4.48E+00	1.33E+02	5.26E+00	-3.25E+03
WDP[2]	m^3 world eq. deprived	7.02E+01	4.65E-02	3.34E+00	7.36E+01	1.20E-01	3.62E+02	0.00E+00	0.00E+00	0.00E+00	1.43E+01	0.00E+00	3.44E+02	0.00E+00	0.00E+00	1.37E-02	1.69E+00	2.26E-01	-3.20E+01

GWP-total = Global Warming Potential total; GWP-fossil= Global Warming Potential fossil fuels (GWP-fossil; GWP-biogenic= Global Warming Potential biogenic; GWP-luluc= Global Warming Potential land use and land use change; ODP = Depletion potential of the stratospheric ozone layer; AP =Acidification potential, Accumulated Exceedance; EP-freshwater = Eutrophication potential, fraction of nutrients reaching freshwater end compartment; EP-marine = Eutrophication potential, fraction of nutrients reaching marine end compartment; EP-terrestrial = Eutrophication potential, Accumulated Exceedance; POCP = Formation potential of tropospheric ozone; ADP-minerals&fossils = Abiotic depletion potential for non-fossil resources; ADP-fossils= Abiotic depletion potential for fossil resources; WDP = Water (user) deprivation potential, deprivation-weighted water consumption.

The measurement of environmental impacts uses the recommended default LCIA methods for the PEF 3.0 method. These methods include amongst others: USEtox® 2.0, ReCiPe (2016), CML-2001, EDIP 2003, IPCC.

[1] To express EP freshwater as kg of PO43- eq, multiply the value for kg P eq. by 3.067

[2] The results of this environmental impact indicator shall be used with care as the uncertainties on these results are high or as there is limited experienced with the indicator.

ND = Module not declared; INA = Indicator not assessed.

5

Figure E.8: EDP of Ventilation Unit

4.B. LCA results

Resource use per one ProAir PA600LI / ProAir PA600PLI Heat Recovery Ventilation Unit

PARAMETER	UNIT	A1	A2	A3	TOTAL A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
PERE	[MJ]	4.70E+02	2.08E-01	8.94E+01	5.59E+02	7.18E-01	1.26E+03	0.00E+00	0.00E+00	0.00E+00	5.30E+01	0.00E+00	7.74E+03	0.00E+00	0.00E+00	7.62E-02	1.64E+01	9.80E-02	-5.31E+02
PERM	[MJ]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PERT	[MJ]	4.70E+02	2.08E-01	8.94E+01	5.59E+02	7.18E-01	1.26E+03	0.00E+00	0.00E+00	0.00E+00	5.30E+01	0.00E+00	7.74E+03	0.00E+00	0.00E+00	7.62E-02	1.64E+01	9.80E-02	-5.31E+02
PENRE	[MJ]	3.31E+03	1.45E+01	3.80E+02	3.70E+03	3.55E+01	1.79E+04	0.00E+00	0.00E+00	0.00E+00	8.70E+02	0.00E+00	4.72E+04	0.00E+00	0.00E+00	4.75E+00	1.41E+02	5.59E+00	-3.45E+03
PENRM	[MJ]	5.11E+02	0.00E+00	0.00E+00	5.11E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PENRT	[MJ]	3.82E+03	1.45E+01	3.80E+02	4.22E+03	3.55E+01	1.79E+04	0.00E+00	0.00E+00	0.00E+00	8.70E+02	0.00E+00	4.72E+04	0.00E+00	0.00E+00	4.75E+00	1.41E+02	5.59E+00	-3.45E+03
SM	[kg]	0.00E+00	0.00E+00	4.69E+02	4.69E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF	[MJ]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF	[MJ]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW	[m³]	3.04E+00	1.58E-03	4.93E-02	3.09E+00	4.75E-03	1.12E+01	0.00E+00	0.00E+00	0.00E+00	4.33E-01	0.00E+00	5.87E+00	0.00E+00	0.00E+00	5.33E-04	7.52E-02	5.51E-03	-3.07E+00

PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water.

ND = Module not declared; INA = Indicator not assessed.

6

Figure E.9: EDP of Ventilation Unit