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Research Article

Performance Evaluation of R1224yd as Alternative to R123 and R245fa for Vapor Compression Heat Pump System

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Abstract

The search for environmentally friendly refrigerants for vapor compression systems has been a significant focus recently due to environmental concerns such as ozone depletion and global warming. In this study, the potential of R1224yd as an alternative refrigerant is investigated. A thermodynamic analysis of a 4-kW air conditioning system is conducted to assess the performance of R1224yd. The system is analyzed from a thermodynamic perspective, and key performance indicators such as the Coefficient of Performance and exergy efficiency. The results are then compared to R245fa and R123. Furthermore, a parametric study is performed to examine the impact of key parameters, such as evaporating and condensing temperatures, on the system's performance. This analysis provides insights into the sensitivity of the system's performance to variations in these parameters. The results indicate that R1224yd is a promising candidate as an environmentally friendly alternative refrigerant compared to R123 and R245fa. Because R1224yd has the lowest environmental impact. It has about 700 kg CO_2 indirect emission, but about zero kgCO_2 for direct emission. While, based on the thermodynamic results, R1224yd offers better performance compared to R245fa which has 1-3% higher in performance value and exergy efficiency, and has comparable performance to R123. This suggests that R1224yd can be a viable option for the systems, providing improved energy efficiency and lower environmental impact.

Keywords: *Warming impact; exergy efficiency; performance; refrigerant; thermodynamic analysis.*

1. Introduction

Recently, one of the hot topics in High Ventilating Air Conditioning and Refrigeration (HVACR) system are the search for alternative working fluid and refrigerant [1]–[9]. Chloro Fluoro Carbons (CFCs) as the first refrigerant for HVAC system banned in 1987 in Montreal Protocol and are being replaced by Hydro Fluoro Carbon (HFC) and Hhdro Chloro Fluoro Carbon (HCFC). In 1996, the phase out of CFC refrigerant had been completed. HFC and HCFC were suggested as the alternative of CFC because it has low Ozone Depletion Potential (ODP). However, in 1990, it was found that suggested refrigerant which have low ODP, contribute to global warming phenomenon. So, in 1997, Kyoto Protocol was issued, the objective is to mitigate global warming by reducing greenhouse gas emissions, which entails advocating for the adoption of refrigerants with low Global Warming Potential (GWP) [10].

The GWP becomes the parameter in identifying priority actions to reduce Green House Gas (GHG) emissions and the impact of climate change. GWP is often used in international environmental regulations and agreements, such as in the Kyoto Protocol, to measure and compare the relative impact of various greenhouse gases on global warming. GWP is a concept used to measure the extent to which certain GHG can have an impact on global warming compared to carbon dioxide (CO_2). This measurement is generally used in comparative contexts, where the GWP of a particular gas is measured in units relative to the CO_2 GWP which has a value of 1. For example, if a gas has a GWP of 25 over a 100 year time period, that means it has a global warming impact 25 times greater than the same amount of CO2 over the same time period.

Many experts have introduced some alternative refrigerants to replace the conventional refrigerant [1], [3], [6], [11], [12]. For example, R1234ze series refrigerant have been widely pointed out as one of the potential alternative refrigerant due to their low flammability, low GWP value, and comparable performance to replace conventional refrigerant such as R134a [11], [13]–[15]. R32 and L41a are also suggested by some researchers as a candidate for R410A replacement because they are characterized by their low GWP value, same characteristics to R410A and having a good performance [10], [12], [16], [17]. Researchers also mention the return to natural refrigerants as alternative refrigerants have raised special interest recently. Nasruddin et al have been conducted research using working fluid mixture 86% R601 and 14% R744 for binary cycle system [2]. Yamaguchi et al also have been done research about using R744 for heat pump system[18]. Hydrocarbons as natural refrigerants are considered as harmless working

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fluids, non-toxic, non-flammable and the important thing that they do not contribute to global warming issue [5], [19]–[22].

To assess the performance of alternative refrigerants and their potential as replacements for conventional ones, a thermodynamic analysis is needed. The study conducted by Park et al [21] in 2008 provides valuable insights into the thermodynamic analysis of a residential heat pump system using R433A as a replacement for R22. R433A is a refrigerant with zero ODP and a lower GWP of less than 5, making it an environmentally friendly alternative. The key finding of the study indicates that coefficient of performance of the system using R433A is 4.9% higher than using R22. The study concludes that R433A is a good substitution for conventional refrigerants with better performance [21]. J Alberto also reported the system's COP and exergy efficiency of cooling system that using alternative refrigerants, R744 [23]. Nawaz K et al, 2017 were having residential heat pump system performance evaluation to compare R600a and R290 refrigerant with R134a. The analysis revealed that both refrigerants could be the option with comparable performance [11]. Recently in 2023, Zhou Dong et al conducted a theoretical study about low GWP refrigerant. The research investigates the thermal efficiency of three refrigerants with low global warming potential, namely R1224yd(Z), R1223zd(E), and R1336mzz(Z), as potential replacements for R245fa. The findings indicated that both R1224yd(Z) and R1223zd(E) exhibited a slightly improved coefficient of performance (COP) compared to R245fa, with R1224yd(Z) showing a 2% increase, and R1223zd(E) showing a 1% increase [24]. While Jiang et al examine the performance of the environmentally friendly refrigerant R1233zd(E) when operating at a temperature lift of 50°C. The experiments were carried out under specific working conditions, including a heat source temperature range of 30–50°C and an output temperature range of 60–100°C. The system achieved a heating capacity of 381 kW and a coefficient of performance (COP) of 3.67 [25].

The purpose of this work is to evaluate the energy and exergy performance of low GWP refrigerant R1224yd theoretically and compare it with the relatively high GWP refrigerants: R245fa and R123. In this paper, parameter study is conducted to investigate the low GWP refrigerant performance, including the effect of different evaporation and condensation temperature. The Total Equivalent Warming Impact (TEWI) analysis also conducted in this paper to examine the best refrigerant among 3 discussed refrigerants. By conducting this study, the suitable refrigerant for vapor compression heat pump system in performance and environmental point of view can be known. It gives recommendations to scientists about the method to select the refrigerant for a system.

2. Working Fluids and System Modelling

In this paper, the working fluids evaluation and system modeling are discussed. Refrigerant evaluation was conducted by examining the fluid properties while the system modelling of heat pump was done by using MATLAB software through thermodynamic considerations.

2.1 Fluid Properties

The selection of a suitable working fluid for a heat pump system involves evaluating several criteria, including thermophysical properties, safety considerations (toxicity and flammability), and environmental factors [2], [26]. Thermo-physical properties such as critical temperature and pressure play a crucial role in this selection process, while environmental factors, especially Global Warming Potential (GWP) becomes an important consideration. Table 1 provides information on the refrigerants discussed in this study, while Figure 1 and 2 illustrates the Ph and Ts diagram for each refrigerant.

Table 1. Properties of discussed refrigerants.

Parameter	R123	R245fa*	R1224yd**
Critical Temp (°C)	183.8	154	155.5
Critical Pressure (MPa)	3.66	3.65	3.33
GWP	77	1030	<1
Safety Group	A2L	B1	A1
Glide Temperature (°C)	-0.2	2	0

Source: *[27], **[28]

R123 and R245fa have relatively good thermal efficiency and tend to be more chemically stable over a wide range of operating conditions and temperatures compared to some of the other alternatives. Wang et al have been conducted a simulation of heat pump system using R123, the results showed that the highest performance of the system can be achieved by using R123 [29].

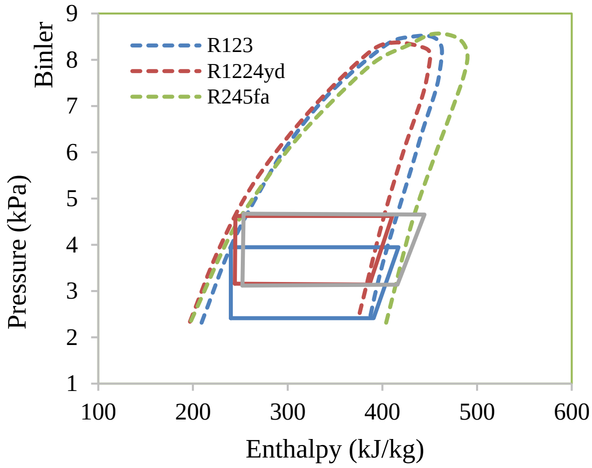

Figure 1. P-h diagram of heat pump cycle with discussed refrigerants.

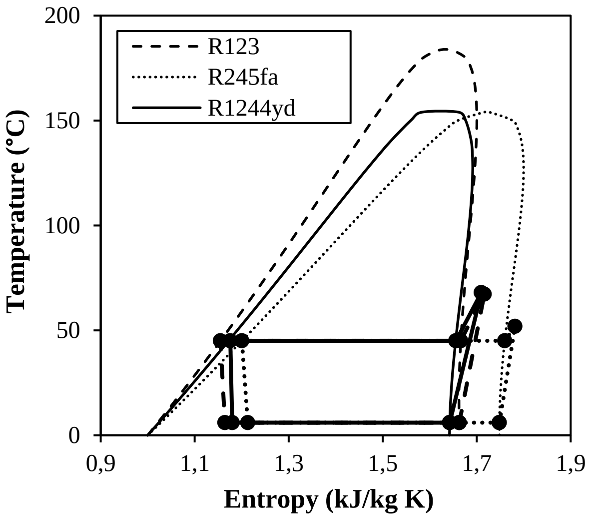

Figure 2. T-s diagram of heat pump cycle with discussed refrigerants.

However, the use of R-123 and R245fa refrigerants have been restricted due to their negative impact on the environment, this can be seen from their GWP value of 77 for R123 and 1030 for R245fa. Thus, many scientists carried out the research for the replacement of R245fa with another alternative refrigerant such as R1233zd(E) [30], [31] and R1336mzz(Z) [32].

Thus, R1224yd appeared to be the replacement of high GWP refrigerant [33]. As an alternative, R1224yd is designed to have minimal impact on the ozone layer, becoming one of alternative refrigerants with a reduced ozone-depleting potential or very small chlorine atom in its structure. Based on the investigation conducted by Akasaka et al. (2017), R1224yd exhibits a high critical temperature and possesses non-flammable and non-toxic properties, making it suitable for use in heat pump systems [34] or even industrial heat pump [33].

2.2 Cycle Description

The vapor compression heat pump cycle depicted in Figure 3 consists of several key components: an evaporator, a compressor, a condenser, and an expansion valve. The cycle operates by supplying external energy to the compressor, which increases the refrigerant temperature and pressure. Subsequently, the high-temperature refrigerant moves into the condenser, where the heat is transferred to the surroundings, resulting in the refrigerant's condensation into a liquid state.

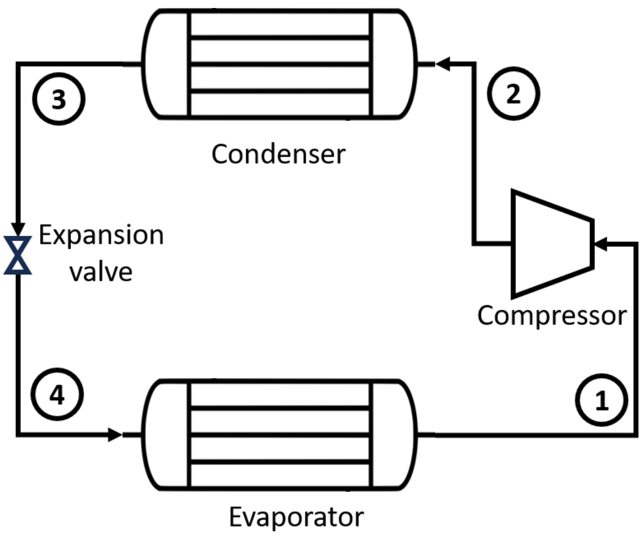

Figure 3. Heat pump system configuration.

The high-pressure refrigerant then passes through the expansion valve, where its pressure is significantly reduced, causing a drop in temperature. The refrigerant, which is at a low pressure and temperature, enters the evaporator and effectively absorbs heat from its surroundings, typically from the environment or a heat source. As a result, the refrigerant evaporates into a gas state, and the heat absorbed during this process is utilized for heating purposes in a heat pump system.

Table 2. Assumed values for the computation process.

Variables	Values
Compressor Issentropic Efficiency	70%
Superheat or subcooled Temperature	0
Heating capacity (kW)	4

The cycle is completed as the low-pressure refrigerant is drawn back into the compressor, and the process begins again. This continuous cycle allows the heat pump system to supply heat to a desired location by transferring heat from a low-temperature source to a higher-temperature destination, utilizing the refrigerant's phase changes and thermodynamic properties.

2.3 Thermodynamic Modelling

In this paper, a thermodynamic model is conducted to compare R1224yd with R245fa and R123. The modelling involves incorporating mass and energy balances, which are crucial for improving the system's efficiency. Some assumptions are made during the component modelling process, including:

1. The system operates under steady-state conditions
2. The impact of pressure and heat loss in the system's pipelines is disregarded.
3. Saturated refrigerant conditions are assumed at the exit of both the evaporator and the condenser, simplifying the analysis by considering the refrigerant in a fully vapor or fully liquid state.
4. The kinetic and potential energies of the refrigerant are not considered in the exergy analysis. This assumption allows the focus to be on the internal energy of the refrigerant and its potential to do useful work.

To conduct simulations and analyze the performance of the cycles, the researchers used MATLAB 2017b software which integrated with REFPROP version 9.0. MATLAB is a widely used programming and numerical computation software that provides various tools and functions for conducting simulations, data analysis, and mathematical modeling. Its integration with REFPROP, which is a program commonly used for thermophysical properties calculations of refrigerants, allowed the researchers to obtain accurate and reliable data for the refrigerants being studied. By utilizing MATLAB and REFPROP together, the researchers were able to perform simulations of the heat pump cycles, incorporating the properties and behavior of the refrigerants at different operating conditions. This combination of software provided the necessary tools and resources to analyze and compare the performance of the different refrigerants under consideration.

Energy and exergy balances play a crucial role in analyzing the performance of system components and evaluating overall system efficiency. Exergy, also known as available energy or useful work potential, represents the maximum work that can be obtained from a given energy source. It provides a measure of the quality of energy within a system, reflecting its potential to do useful work. To conduct a comprehensive analysis, the general equation of mass, energy, and exergy balances for each component in the system are considered. These balances are defined as follows [35]:

$$\sum \dot{m}_{in} = \sum \dot{m}_{out} \quad (1)$$

While ṁ is the mass flow rate and the subscripts in to describe input and out is output. The first law of thermodynamic is written as:

$$\dot{Q}_{in} + \dot{W}_{in} + \dot{m}h_{in} = \dot{Q}_{out} + \dot{W}_{out} + \dot{m}h_{out} \quad (2)$$

Where $\dot{Q}$ is the heat transfer rate between control volume and its surroundings, $\dot{W}$ is the work rate, and h is the specific enthalpy.

The Coefficient of Performance (COP) is a metric used to evaluate the energy efficiency of a heat pump system. It is defined as the ratio of the heat rejected in condenser to the total power consumption (the compressor total energy consumed). The calculation of COP can be expressed as:

$$COP=\frac{\dot{Q}_{cond}}{\dot{W}_{comp}} \quad (3)$$

With the second law of thermodynamics and exergy principles, the following general exergy rate balance can be written:

$$\dot{Ex}_Q+\sum_i \dot{m}_i \dot{ex}_i=\sum_e \dot{m}_e \dot{ex}_e+\dot{Ex}_W+\dot{Ex}_D \quad (4)$$

The energy and exergy analysis are conducted based on thermodynamic analysis and mass balance equations which are listed in Eqs. (5-16).

For evaporator,

$$\dot{m}_1=\dot{m}_4 \quad (5)$$

$$\dot{Q}_c=\dot{m}_{ref}(h_1-h_4) \quad (6)$$

$$\dot{Ex}_e=\dot{m}_{ref}(Ex_4-Ex_1)+[1-(T_a-T_{cl})]\dot{Q}_e \quad (7)$$

For compressor,

$$\dot{m}_1=\dot{m}_2 \quad (8)$$

$$W_{co}=\dot{m}_{ref}(h_2-h_1) \quad (9)$$

$$Ex_{co}=W_{co}-\dot{m}_{ref}(Ex_2-Ex_1) \quad (10)$$

For condenser,

$$\dot{m}_2=\dot{m}_3 \quad (11)$$

$$Q_c=\dot{m}_{ref}(h_2-h_3) \quad (12)$$

$$Ex_c=\dot{m}_{ref}(Ex_2-Ex_3)-[1-(T_a-T_c)]Q_c \quad (13)$$

For expansion valve,

$$\dot{m}_3=\dot{m}_4 \quad (14)$$

$$h_3=h_4 \quad (15)$$

$$Ex_v=\dot{m}_{ref}(Ex_5-Ex_6) \quad (16)$$

Exergy analysis is based on the first and second laws of thermodynamics. These equations, along with other thermodynamic relationships, are used to evaluate the energy and exergy transfers, efficiencies, and losses within a system. They provide valuable insights into the performance and optimization potential of the system. In vapor compression heat pump, the work of compressor considers as the input exergy while the exergy of product is the exergy of heat in evaporator from the space to be cooled in which the equation is given by:

$$Ex_{in}=W_{co} \quad (17)$$

Then, the exergy destruction and exergy efficiency of the system can be calculated by using:

$$Ex_{D;tot}=Ex_e+Ex_{co}+Ex_c+Ex_v \quad (18)$$

$$Ex_{eff}=1-\frac{Ex_{D;tot}}{Ex_{in}} \quad (19)$$

2.4 Total Equivalent Warming Impact (TEWI) Analysis

In evaluating the selection of the refrigerant used, this research analyzed the environmental aspects, specifically focusing on the Total Equivalent Warming Impact (TEWI) as outlined in Mastrullo's work (2016). The TEWI values considered in this investigation are provided in Eq. (20).

$$\begin{aligned} TEWI &= \text{direct emissions} + \text{indirect emissions} \\ &= (GWP \times L \times N) + (Ea\ \beta\ n) \end{aligned} \quad (20)$$

where

TEWI : Total Equivalent Warming Impact (TEWI)
GWP: Global Warming Potential value
L : Leakage rate in kg (Estimated 3% of charge)
N : System lifetime (years)
Ea : Energy consumption (KWh/year)
β : CO_2 emission factor (0.483 kg CO_2/kWh)
n : System running time in one year.

3. Results and Discussions

In this paper, three refrigerants are discussed: R123, R245fa, and R1224yd. These refrigerants are evaluated based on their physical properties and environmental impact called TEWI analysis. Then, a system was modelled, and exergy analysis was carried out.

3.1 Evaluation of Refrigerants

The evaluation of refrigerants typically considers their physical properties and environmental effects Physical properties such as critical temperature, and critical pressure are important factors in determining the suitability of a refrigerant for a particular application. These properties affect the refrigerant's performance in terms of heat transfer, energy efficiency, and system design.

In addition to physical properties, environmental factors are crucial considerations. These include ODP, GWP and Total Equivalent Warming Index (TEWI) of the refrigerant. ODP measures the potential for a substance to deplete the ozone layer, while GWP quantifies the impact of a substance on global warming compared to carbon dioxide. Low ODP and GWP values are desirable as they indicate a reduced environmental impact. But, in this study the ODP value was considered absolute, and it was known that the ODP value of the three discussed refrigerants was 0. So only GWP is included in the consideration.

The evaluation of these three refrigerants, R123, R245fa, and R1224yd, likely involves a comparison of their physical properties, and GWP values. This analysis helps determine their suitability for various applications, considering both performance and environmental considerations. The goal is to identify whether R1244yd is the best alternative refrigerant. Figure 4 illustrates the trend of thermodynamic properties, including pressure and temperature of discussed refrigerants.

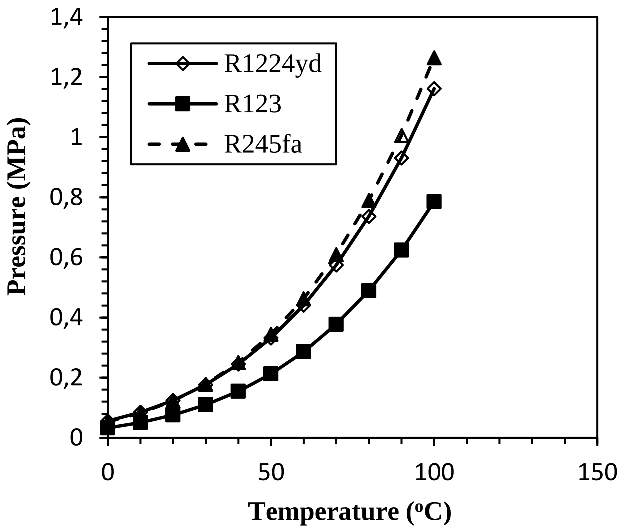

Figure 4. Temperature vs pressure of discussed refrigerants.

From figure 4, three refrigerants have nearly the same temperature and pressure range. Due to their similar properties, R1224yd can be a potential candidate compared to R123 and R245fa without any change in design pressure. Besides considering the thermodynamic properties of refrigerants, some parameters such as GWP and safety group of refrigerants were considered. Table 3 gives the result of refrigerant evaluation from 5 parameters including critical pressure, critical temperature, safety group, GWP, and glide temperature.

Table 3. Standardized data.

Parameters	R123	R245fa	R1224yd
Critical Temperature	1	1	1
Critical Pressure	0.956	0.959	1
GWP	0.77	0	1
Safety Group	0.75	0.5	1
Glide Temperature	1	0.2	1

In order to easier understand the data from Table 2, a spider plot is designed. Figure 5 shows spider plot of refrigerant evaluation procedure.

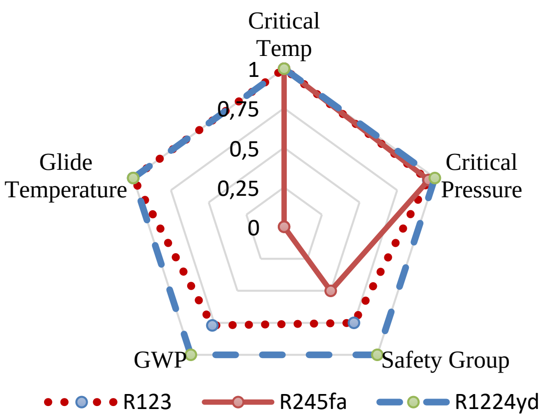

Figure 5. Evaluation of physical properties of three discussed refrigerants using spider plot.

From Figure 5, Based on the mentioned criteria and considerations, it can be concluded that R1224yd is the best refrigerant which is environmentally friendly. Its properties, such as low GWP and favorable safety characteristics, make it a promising option. To further evaluate the environmental impact, TEWI analysis was conducted as seen in Figure 6. TEWI takes into account both direct and indirect emissions of greenhouse gases throughout the life cycle of the refrigeration system. This analysis helps assess the overall environmental performance of different refrigerants, including R1224yd, R245fa, and R123.

By comparing the TEWI values for these refrigerants, it is possible to determine their respective contributions to global warming potential and environmental impact. This analysis provides valuable insights into the sustainability and efficiency of the heat pump system using each refrigerant.

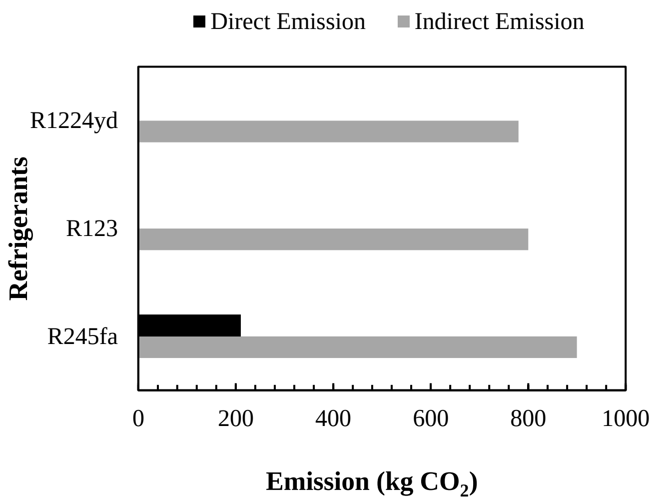

Figure 6. TEWI of refrigerant regarding to environmental effect.

From Figure 6, it can be seen that R245fa has the highest value both of indirect emission and direct emission of CO_2 compared to others. It has about 900 $kgCO_2$ indirect emission and about 200 $kgCO_2$ for direct emission. The suggested refrigerant, R1224yd has the lowest environment impact. It has about 700 kg CO_2 indirect emission, but about zero $kgCO_2$ for direct emission. Overall, considering the environmental criteria, thermodynamic properties, safety considerations, and TEWI analysis, R1224yd demonstrates favorable characteristics as a potential replacement refrigerant for heat pump systems.

3.2 Comparison Performance of R1224yd, R123, and R245fa

After considering the physical properties and environmental impact parameters, R1224yd emerges as the most promising candidate among the others. The next step is to evaluate the performance of the system using this refrigerant. This involves conducting a parameter study and system performance evaluation. In the parameter study, the evaporating temperature varies within a specific range, such as from 8°C to 16°C. Additionally, the condensing temperature varies at different set points, such as 40°C, 43°C, 46°C, and 49°C. These variations allow for an analysis of the system's performance under different operating conditions.

This evaluation enables engineers and researchers to make informed decisions regarding the selection of the refrigerant and optimize the system's performance for specific applications. Under the same condition the result was compared and are shown in Fig 7-12. A computer program developed in MatLab and integrated with REFPROP was used to solve the equations. With the given input parameters including evaporator temperature, condenser temperature, ambient temperature, cooling capacity, the program calculates all thermodynamic properties of each point of the cycle, energy and exergy efficiencies and exergy destruction.

3.2.1 Effect of Evaporation and Condensation Temperature on the COP System

Refrigerant changes its phase from liquid to vapor in evaporator. If the evaporator temperature is increased constantly from 8 ºC to 16 ºC, the performance of the system, which is indicated by COP is increased as illustrated in Figure 7. This is due to the complete refrigerant evaporation occurring at higher temperature of evaporator. The value of COP ranges from 4.6 to 6.5, with the work of compressor ranges from 0.61 – 0.85 kW. There is the same tradeoff for R1224yd, R123 and R245fa.

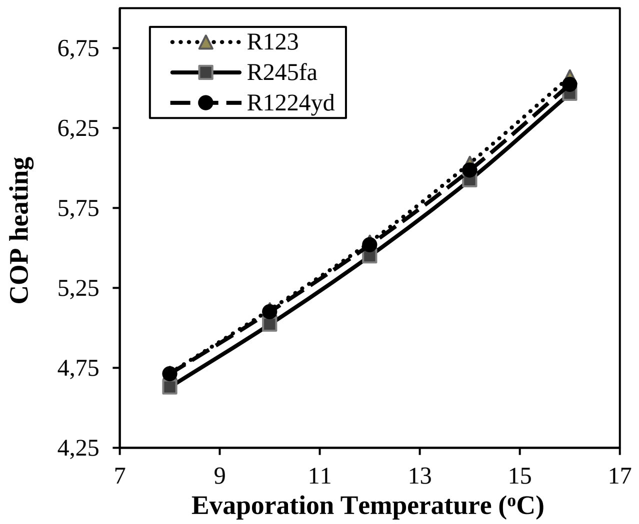

Figure 7. COP comparison for R245fa, R123 and R1224yd at various evaporating temperatures.

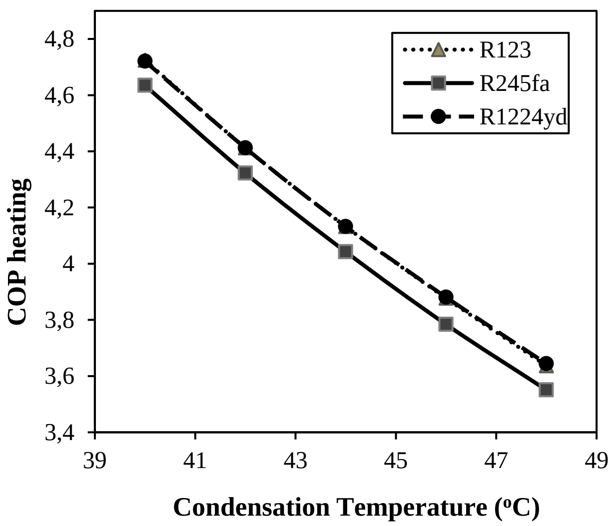

Figure 8. COP comparison for R245fa, R123 and R1224yd at various condensing temperatures.

While the increase in condensation temperature from 40 ºC to 48 ºC, decreases the COP from 4.7 to 3.6 as seen in Figure 8. This reveals that the heat pump could improve the system COP by increasing the evaporating temperature and decreasing condensing temperature. From Figure 8, performance of R1224yd has nearly the same trend as R123. COP of both refrigerants increase linearly with increasing evaporation temperature. As it is illustrated in the graph, R1224yd has better performance than R245fa with COP difference between both refrigerants is 1-3%. Finally, considering the performance evaluation and the environmental effect, R1224yd which has <1 of GWP value is a good replacement for R245fa.

3.2.2 Effect of Evaporation and Condensation Temperature on the Exergy

As is known, exergy is an important parameter to evaluate the maximum work that can be produced by the system. Exergy indicates the performance of the system. Figures 9 and 10 present the exergy efficiency of the system while Figures 11 and 12 show the exergy destruction of the system with various evaporation and condensation temperatures.

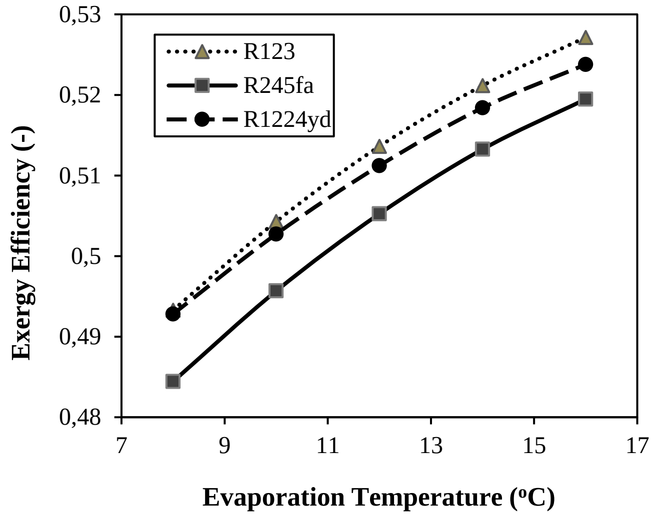

Figure 9. Exergy efficiency of the system at various evaporator temperatures.

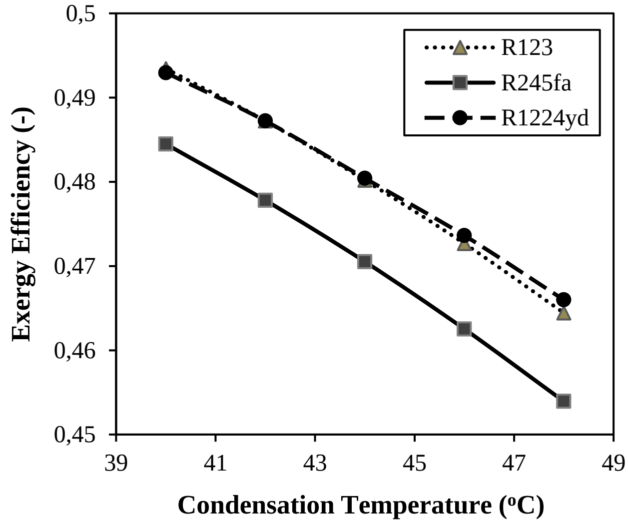

Figure 10. Exergy efficiency of the system at various condenser temperatures.

From Figure 9 and Figure 10, the exergy efficiency of the system using R1224yd is higher than R245fa and nearly has the same amount as R123. Relevant to the result from Figure 9, in Figure 11, the exergy destruction total of R1224yd has the lowest amount compared to R123 and R245fa.

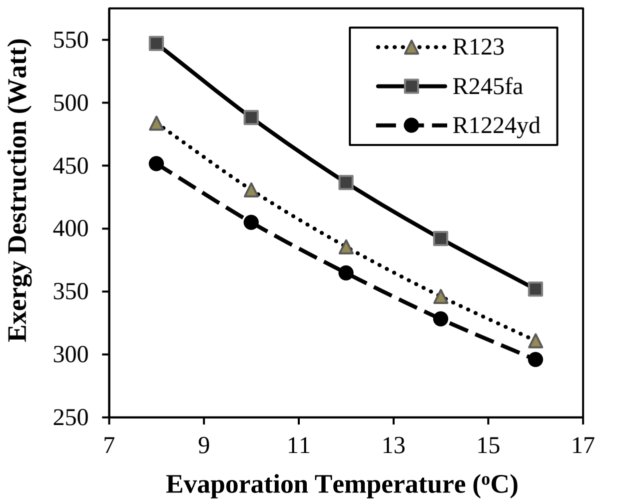

Figure 11. Exergy destruction of the system at various evaporator temperatures.

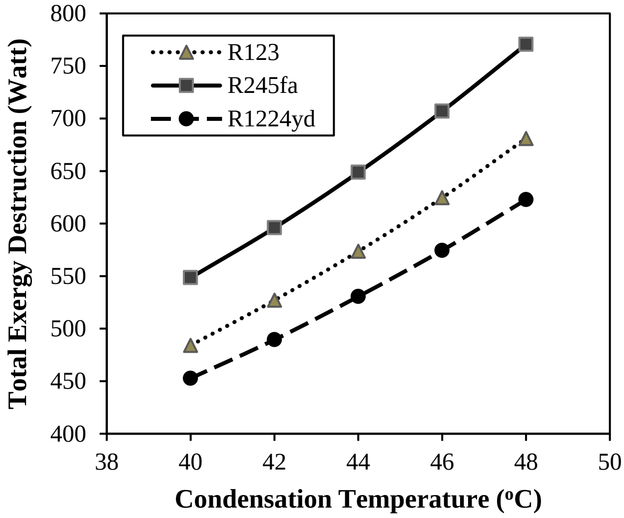

Figure 12. Exergy destruction of the system at various condenser temperatures.

From this parametric study, it observed that energy and exergy efficiencies increase when evaporating temperature increases and decrease when the condensation temperature increases. The increase in the evaporating temperature, causing the augmentation of the cooling capacity and the reduction of the compressor pressure ratio and the compressor work. Thus, COP and exergy efficiency increase. The increase in the condenser temperature is causing an increase of the pressure ratio across the compressor and its required work. Then the COP and exergy efficiency decreases.

3.3 Exergy Analysis for Each Component of the System

Figure 13 represents the exergy destruction total of four main components with variation in evaporating temperature, while Figure 14 shows the percentage of exergy destruction for each system component.

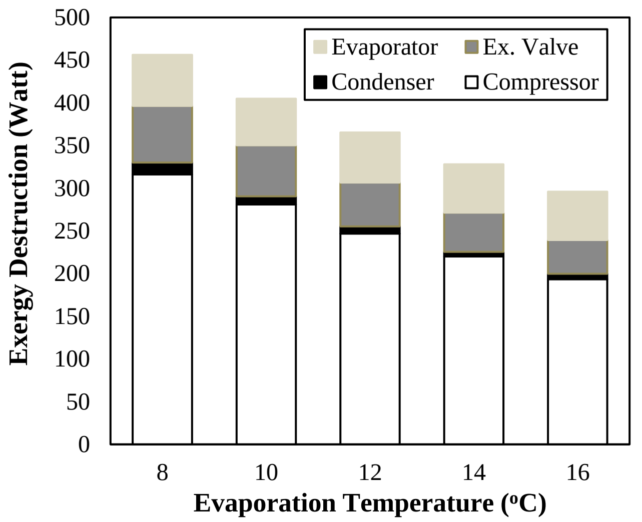

Figure 13. Effect of evaporation temperature on total exergy destruction at each component.

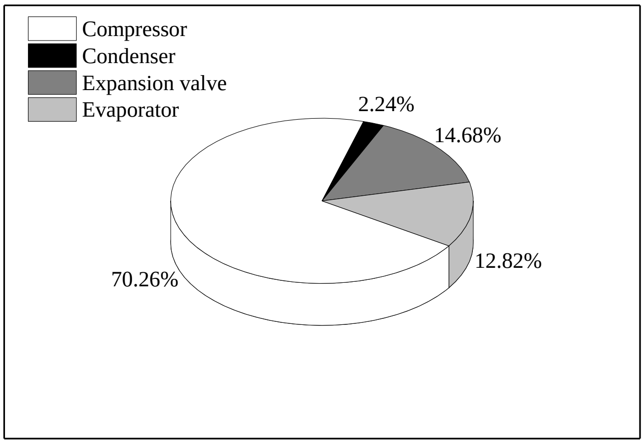

Figure 14. Percentage of exergy destruction at each component of the system.

According to Figure 14, the analysis reveals that the compressor causes the most significant loss of exergy in the heat pump system, followed by the expansion valve, evaporator, and condenser. This observation is consistent with the fact that compressors typically exhibit higher exergy losses compared to other components. The exergy destruction in the compressor is primarily due to several factors such as electrical losses, mechanical losses, and isentropic efficiency losses. These losses contribute to a significant portion of the total exergy destruction within the system. In the given analysis, it is observed that the compressor alone accounts for approximately 70% of the total exergy destruction, which amounts to around 300 Watts. The second largest component of exergy loss is found in the expansion valve and evaporator. The losses in the evaporator can be attributed to several factors, including the rise in temperature at the end of the evaporation process, which creates a temperature difference in the heat transfer process and with the surroundings.

Understanding the distribution of exergy destruction among the system components is crucial for identifying areas of potential improvement and optimization. By focusing on minimizing exergy losses in the compressor, as well as improving the performance of the expansion valve and evaporator, engineers can enhance the overall efficiency and performance of the heat pump system.

4. Conclusions

A vapor compression heat pump system with capacity of 4 kW was performed in this work. The energy and exergy analysis of low GWP refrigerant, R1224yd compared to R245fa to investigate the feasibility of using R1224yd as a substitute for R245fa which has high GWP value. R1224yd has similar physical properties to R245fa. A parametric study was conducted to ascertain the effect of evaporation and condensation temperature on energy and also exergy efficiencies. From the result, it is observed that energy and exergy efficiencies increase when evaporating temperature increases and decrease when the condensation temperature increases. Also, based on the thermodynamic modeling results, R1224yd offers better performance compared to R245fa which has 1-3% higher both in COP value and exergy efficiency. While R1224yd has the comparable performance with R123. In other words, it can be concluded that in thermodynamic and environmental point of view R1224yd is found to be potential candidate to replace R245fa and R123.

Nomenclature

$\dot{m}_{in}$: massflow rate input (kg/s)
$\dot{m}_{out}$: massflow rate output (kg/s)
$\dot{Q}_{in}$: heat transfer rate input (Watt)
$\dot{W}_{in}$: work input (Watt)
h_{in} : enthalpy input (kJ/kg)
$\dot{Q}_{out}$: heat transfer rate output (Watt)
$\dot{W}_{out}$: work output (Watt)
h_{out} : enthalpy output (kJ/kg)
COP : Coefficient of Performance
$\dot{Q}_e$: heat transfer rate in evaporator (Watt)
$\dot{Q}_c$: heat transfer rate in condenser (Watt)
$\dot{W}_{comp}$: work of compressor (Watt)
$\frac{\dot{Q}_i}{T_i}$: entropy rate transfer (Watt/K)
s : specific entropy (kJ/kh K)
s_{gen} : entropy rate generation (kJ/kh K)
m_{ref} : mass flowrate of refrigerant (kg/s)
Ex_e : exergy destruction in evaporator (Watt)
Ex_{co} : exergy destruction in compressor (Watt)
Ex_c : exergy destruction in condenser (Watt)
Ex_v : exergy destruction in valve (Watt)
Ta : Ambient temperature (^oC)
Ex_{in} : exergy input (Watt)
$Ex_{D;tot}$: total exergy destruction (Watt)
Ex_{eff} : exergy efficiency (%)

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