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Integration of Water Heating Systems with Car Air Conditioning Systems: A Bibliometric Analysis, Lab-scale Investigation, and Potential Applications

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A B S T R A C T

Automotive air conditioning (AC) systems, traditionally powered by the engine, contribute to reduced fuel efficiency and environmental challenges. However, the heat released by the AC condenser has the potential for energy reuse. This study aims to design and evaluate an integrated thermal management system that combines the functions of a water heater and an AC. A lab-scale system is developed to investigate the thermodynamic behavior of the refrigerant and assess the system performance at various cooling water flow rates. The results show an increase in the Energy Efficiency Ratio (EER) with this integration, which offers new applications, such as intercity buses by providing warm water for on-board toilets. This innovation not only improves passenger comfort but also improves energy efficiency and sustainability in transportation systems. The proposed integration is an example of a practical approach to utilize waste heat and address energy and environmental issues in modern vehicles.

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1. INTRODUCTION

The development of car air conditioning (A/C) systems has a long history. Before 1940, people relied on manual methods to maintain comfort and coolness in their enclosed cars [1]. Although the first scientific report found in the Scopus database discussing thermal comfort in vehicles was in 1933, commercial cars equipped with A/C systems were only introduced by Packard in 1940 as an optional feature. In the initial models, the cooling system was placed in the trunk and lacked interior controls. By 1969, over half of all new cars sold featured A/C systems with controllable vapor compression. Gradually, automobile A/C systems evolved not only with vapor compression systems but also involved other non-conventional systems and modern additional arrangements, as we reviewed in our previous, where the cooling potential of LPG vaporizer contributed about 26% of the air AC performance during eco-friendly driving conditions study [2]. Other previous papers relating to air conditioning are presented in **Table 1**.

Table 1. Previous papers relating to air conditioning.

No	Research topic	Ref.
1	Cooling effects in LPG-fueled vehicles using a lab-scale prototype	[3]
2	Impact of room temperature settings on cooling load estimation in an educational building using CLTD method	[4]
3	Evaporator effectiveness in ½ cycle refrigeration systems for LPG-fueled vehicles	[5]
4	Reducing car cabin temperature using solar-powered mini air coolers	[6]
5	Solar-powered cooling system for parked cars	[7]
6	Reducing temperature and heat index in parked vehicles under sunlight	[8]
7	Cooling power harvesting in LPG-fueled vehicles using a vaporizer-chiller system as a secondary air conditioning solution	[9]
8	Automatic control system for air conditioning in passenger cars to maintain thermal comfort and health standards	[10]
9	Cooling effect in LPG-fueled vehicles using air flow for vaporization	[11]
10	Exploring the use of propane (R290) as a natural refrigerant in food transport refrigeration systems in Southern Africa	[12]
11	Optimization of automotive air-conditioning system performance using Taguchi's design	[13]
12	Performance analysis of eco-friendly refrigerant blends as substitutes for R410A in air-conditioning systems	[14]
13	Combined power and cooling solar organic rankine cycle with ammonia-water refrigeration	[15]
14	Thermoelectric cooling systems as an alternative to conventional air conditioners for parked car cabins	[16]

The term A/C, which was originally correlated with the cooling system, was later developed to involve temperature, humidity, and air quality in the cabin, which became known more widely as a heating, ventilating, and air-conditioning (HVAC) system. The development of conventional A/C systems and heat pumps for vehicles has been discussed in depth [17]. Meanwhile, technology to improve the performance of A/C systems has also been studied and presented comprehensively [18]. In addition, active, passive, and hybrid A/C systems have also been studied and described in detail regarding their impact on vehicle performance [19]. The use of alternative refrigerants has also been widely studied to improve system performance and reduce the impact of global warming [12, 14, 20-23]. Recently, research on HVAC in automobiles has developed into efficient and more sustainable technologies to be compatible with electric vehicles [24-33].

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Although A/C systems have developed rapidly, as long as the energy to drive the system is taken from the engine, it will overload the engine and increase fuel consumption [29, 34-36]. Therefore, new systems were developed to reduce the engine load, including adsorption systems [37-41] and the use of solar energy as a power supply [42-44]. It might be an alternative solution in the future while it continues to be developed. In addition, to reduce engine power loss due to AC compressors, in recent years a special AC system has been developed for LPG-fueled vehicles by utilizing the cooling effect of the LPG evaporation process before it is fed to the engine [5, 9, 11, 45, 46]. The cooling power from the LPG evaporation cannot yet be as great as the original vapor compression A/C system, but it is promising to be applied as a secondary system.

In general, vapor compression A/C systems in cars are operated to provide cooling or heating to the cabin to achieve thermal comfort. In a vapor compression system, the evaporator provides the cooling effect to maintain cabin temperature, while the condenser releases the heat carried by the refrigerant into the surrounding environment [47]. Because the heat released to the environment is considered to compensate for the work of the refrigeration system, only the cooling effect of the evaporator is considered in assessing the performance of the A/C system, which is defined as COP or EER. If the heat released by the condenser is used, for example, to provide hot water in a bus toilet reservoir, the recovered heat can be converted into new benefits, so that the COP or EER increases.

Therefore, our present study aims to design a thermal management system by integrating the water heating system and an A/C system. Conceptually, the cold water in the reservoir will be pumped across the A/C condenser so that heat exchange occurs which helps cool the condenser while also producing warm water to be returned to the reservoir [48]. In this study, the thermodynamic behavior of refrigerants in A/C systems and water heating systems is investigated. Heat exchange in the condenser is observed at several water mass flow rates, while heat exchange in the evaporator is calculated by involving environmental air humidity and condensed water vapor during the air passing through the evaporator. In addition, the overall thermodynamic performance of the system is also analyzed to provide a more comprehensive interpretation.

To enhance the analysis, computational bibliometric analysis was involved. This method is recognized as an effective approach to identify current research trends and to identify the research gap [49-59]. We have searched for articles relevant to this study in Google Scholar and Scopus databases. Advanced searching in Google Scholar with the keyword "allintitle: Water Heater, Air Conditioning" found 17 relevant articles. After further analysis, only 9 of the 17 references were published in journals and proceedings in English, the rest included reports and articles that were not accessible, articles written in local languages, or did not include titles and abstracts in English. Meanwhile, searching in the Scopus database in the category "article title" found 5 articles, all of which were also found in Google Scholar. A summary of resources is presented in **Table 2**. From the literature studied, we found that Air Conditioning Water Heater (ACWH) systems are a growing area of interest in HVAC research, offering potential energy savings and multifunctional benefits by combining space cooling, heating, and water heating.

In terms of working principles and features, the ACWH system can be operated in multiple modes, including water heating, air conditioning, space heating, and their combinations. Based on other study, tested the prototype in various ambient temperatures and demonstrated stable operation. Their prototype was able to work efficiently in all modes, indicating significant energy savings compared with traditional systems. Refrigerant selection also has a significant impact on the performance and environmental impact of ACWH systems.

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Studies comparing natural refrigerants such as R290 with conventional options such as R417A have shown that R290 offers higher COP, lower energy consumption, and is more environmentally friendly due to lower refrigerant charging requirements and lower global warming potential [60].

Table 2. Summary of search results in Google Scholar and Scopus databases.

No	Research topic	Ref.	Sources		
			P	GS	Scopus
1	Comparison of R290 and R417A as refrigerants in a heat pump air conditioning water heater system	[60]	P	√	√
2	Performance enhancement of Split AC with trombone coil as heat pump water heater	[61]	J	√	√
3	Energy-efficient water heater using waste heat from air conditioner	[62]	J	√	√
4	Improving thermal efficiency of water heaters by recovering waste heat from air conditioners	[63]	J	√	√
5	Effect of trombone coil diameter and length on the performance of ASACWH for water heating	[64]	J	√	√
6	Improving COP of heat pump water heaters using waste heat recovery from condenser cooling water	[65]	J	√	
7	Energy efficiency in combined refrigerator, air-conditioner, and heater system	[66]	J	√	

Note: P: Proceeding; J: Journal; GS: Google Scholar

In addition, several studies have examined heat recovery from air conditioners to improve system efficiency. Combinations of waste heat recovery, such as trombone coil condensers, have been shown to improve the Coefficient of Performance (COP) and overall energy efficiency. For example, waste heat recovery from split-type air conditioners has increased the water heating capacity and overall COP with minimal impact on cooling performance [61, 62]. Innovations in ACWH systems have focused on optimizing design and operation to maximize energy savings. Recent advances include the use of double-tube heat exchangers to recover heat more efficiently, resulting in substantial improvements in thermal efficiency and reduced energy consumption of air conditioning units [63]. Design parameters, such as coil diameter and length in trombone coil condensers, have also been studied, showing that certain configurations can increase cooling capacity and COP while maintaining comfortable room temperatures [64]. In general, the integration of ACWH systems with conventional air conditioning and heating systems offers three benefits: cooling, heating, and water heating. This multifunctionality not only improves energy efficiency but also provides a sustainable solution to reduce carbon emissions and mitigate global warming [65, 66].

In summary, the ACWH system enhances energy efficiency and minimizes environmental impact by recovering waste heat and optimizing the use of refrigerants. This system has the potential to play an important role in sustainable practices, offering a feasible solution for space cooling, heating, and water heating simultaneously. However, the literature reviewed that discusses the combination of AC and water heating systems for vehicle or bus applications is still very limited, except in our previous study which does not consider the condensed water in the evaporator [48]. Therefore, this study proposes a novel idea, where the automotive AC system and water heater are combined to provide air cooling and water heating effects simultaneously.

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2. METHODS

2.1. Experimental Setup

In this research, a small-scale car AC system is combined with a water heating system as shown in **Figure 1**. The AC system in the top loop consists of a compressor, condenser, dryer, expansion valve, and evaporator. The compressor is used to circulate R-134a refrigerant to produce a vapor compression refrigeration cycle. The condenser, which was initially cooled with a forced air convection system, was replaced by the water-cooling system. All sides of the condenser are immersed in water in a heat exchanger box with the size of 60 x 11 x 41.5 cm. Thus, heat exchange can occur more efficiently. The water in the heat exchanger is circulated by an electric water pump AM-104A from the reservoir.

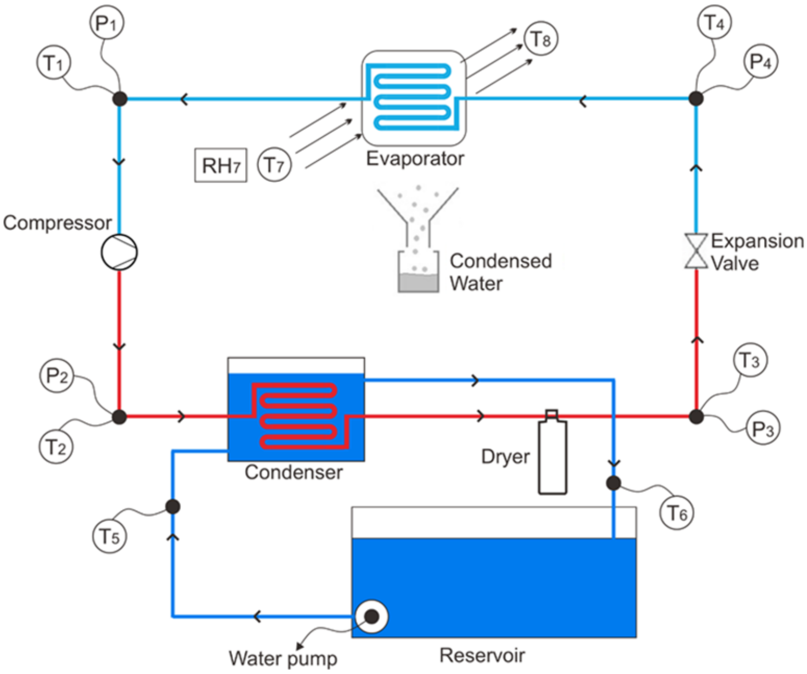

Figure 1. Experimental setup.

To calculate the performance of the A/C system, thermocouples and pressure transducers were installed at all specific state points in the A/C system. P_1 and T_1 functioned to measure the pressure and temperature of the refrigerant entering the compressor, P_2, and T_2 functioned to measure the pressure and temperature of the refrigerant entering the condenser, P_3 and T_3 functioned to measure the pressure and temperature of the refrigerant entering the expansion valve, and P_4 and T_4 functioned to measure the pressure and temperature of the refrigerant entering the evaporator. On the water heating system side, T_5 was installed to measure the water temperature in the reservoir, and T_6 was used to measure the water temperature exiting the heat exchanger. T_7 was used to measure the environmental temperature, and T_8 was used to measure the air temperature exiting the evaporator. Meanwhile, RH_7 was used to measure the relative humidity of the air entering the evaporator. All pressure, temperature, and humidity data collected were transmitted to the data logger for analysis using the DAQ Master software. Autonics products were employed for all measuring instruments and software utilized in this research. CSV file from DAQ master then processed using Ms. Excel to avoid manual calculation errors.

Furthermore, to determine the rate of heat transfer from the condenser to water in the heat exchanger (q_c) is calculated by multiplying the mass flow rate of water ($\dot{m}_w$) with the specific heat of water (C_{pw}) and the difference in water temperature when entering and

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leaving the heat exchanger (ΔT). In this research, the mass flow rate of water ($\dot{m}_w$) is varied at 0.025, 0.050, 0.075, and 0.100 kg/s to further determine its effect on the heat transfer rate and the performance of the A/C system.

2.2. System Description and Thermodynamics Analysis

According to **Figure 1**, this study involves the thermodynamic processes of a vapor compression refrigeration system and a heating system. In a vapor compression refrigeration system, power is provided by the compressor (W_c) to increase the refrigerant pressure from specific state (1) to (2), isentropically. Apart from the compressor, the evaporator box also employs an electric blower (W_{eb}) to circulate air through the evaporator fins from specific state points (7) to (8). On the other hand, the condenser which was initially cooled by forced air driven by an electric fan was replaced with water circulation powered by a water pump (W_p) so that water flows from a specific state point (5) to (6). The power of compressors, electric blowers, and water pumps is calculated by measuring the voltage and current consumed while they work. Thus, the total power required by this system is the sum of the compressor work, electric blower work, and water pump work at a certain time, as formulated in equation (1).

$$W_t = W_c + W_{eb} + W_p \tag{1}$$

In this study, apart from the cooling power (q_{ev}) which is harvested in the evaporator, heating power (q_c) is also obtained from the condenser to the water in the heat exchanger box, which is calculated by equation (2), where $\dot{m}_w$ is the mass flow rate of water in the heat exchanger (kg/s), C_{pw} is the specific heat of water (kJ/kg°C). T_5 and T_6 are the temperature of the water at the inlet and outlet of the heat exchanger, respectively. Meanwhile, the refrigeration effect is calculated on the air side, as calculated by equation (3), where $\dot{m}_a$ is the mass flow rate of air across the evaporator (kg/s). h_7 and h_8 are the enthalpies of the air at the evaporator inlet and outlet, respectively. Therefore, the total thermal energy harvested is given in equation (4).

$$q_c = \dot{m}_w \, C_{pw} \, (T_6 - T_5) \tag{2}$$
$$q_{ev} = \dot{m}_a (h_8 - h_7) \tag{3}$$
$$q_t = q_{ev} + q_c \tag{4}$$

To determine the enthalpy of air at the evaporator inlet and outlet, because some of the water vapor is condensed as it passes through the evaporator fins, the temperature and humidity of the air entering the evaporator are also measured, so that the mixing ratio of water vapor to dry air, X(kg/kg) can be calculated as with equation (5), where *B* is the ratio of M(H_2O) to M(air) defined as 621.9907 g/kg. P_w and P_{tot} are the water vapor pressure and total ambient pressure, respectively. Meanwhile, P_w is calculated by equation (6). Additionally, X in the air leaving the evaporator is calculated by subtracting the water condensation rate from X in the air entering the evaporator.

$$X = \frac{B \cdot P_w}{(P_{tot} - P_w)} \tag{5}$$
$$P_w = P_{ws} \cdot \frac{RH}{100} \tag{6}$$

where P_{ws} and RH are the water vapor saturation pressure and relative humidity (%), respectively. P_{ws} is obtained by equation (7).

$$P_{ws} = A \cdot 10^{\left[\frac{m \cdot T}{T + T_n}\right]} \tag{7}$$

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where T is the measured temperature at specific state points *A, m,* and T_n are the constant values of 6.116441, 7.591386, and 240.7263, respectively. Finally, h is obtained by equation (8).

$$h = h_a + X\, h_w \tag{8}$$

where h is specific enthalpy of moist air (kJ/kg), h_a is specific enthalpy of dry air (kJ/kg), X is the mixing ratio (kg/kg), and h_w is the specific enthalpy of water vapor (kJ/kg). Assuming the system works at constant pressure, the specific enthalpy of dry air (sensible heat) is calculated by equation (9), where C_{pa} is the specific heat of air at constant pressure (1.006 kJ/kg°C) and T is the air temperature (°C).

$$h_a = C_{pa}T \tag{9}$$

Meanwhile, the specific enthalpy for water vapor (latent heat) is calculated using equation (10), where C_{pw} is specific heat of water vapor at constant pressure (1.86 kJ/kg°C), T is the water vapor temperature (°C), dan h_{we} is the evaporation heat of water at 0 °C (kJ/kg).

$$h_w = C_{pw}T + h_{we} \tag{10}$$

Finally, overall system performance (*EER*) by comparing the utilized thermal energy (q_t) as calculated by equation (4) to total work (W_t) as calculated by equation (1), to produce *EER* as expressed in equation (11).

$$EER = \frac{q_t}{W_t} \tag{11}$$

3. RESULTS AND DISCUSSION

3.1. Refrigerant Temperature and Pressure Behaviour

Figures 2(a-d) show the measured refrigerant temperature and pressure at water mass flow rates of 0.025, 0.050, 0.070, and 0.100 kg/s. At specific state point (1), where the refrigerant enters the compressor, the highest temperature and pressure are produced at a water flow rate of 0.100 kg/s, as shown by the solid black line for temperature and the dashed black line for pressure in **Figure 2(a)**. The compressor increases the refrigerant pressure, which is then followed by an increase in temperature as shown in **Figure 2(b)**. The refrigerant is condensed in the condenser as shown by the dashed curves in **Figure 2(b)** and **Figure 2(c)**, which respectively represent the condition of the refrigerant when it enters and leaves the condenser (entering the expansion valve), respectively. In this study, the heat released by the refrigerant was fully absorbed by the water circulating within the heat exchanger. Ideally, the condensation process occurs isobarically; however, in our findings, a pressure drop was observed, likely due to the thermophysical properties of the refrigerant and the design of the condenser [67-70]. Finally, the refrigerant is expanded and enters the evaporator, as shown in **Figure 2(d)**.

The testing process results in two distinct phases: transient and steady state. Initially, temperature and pressure exhibit transient behavior before stabilizing at different steady levels. The pressure stabilizes more rapidly compared to temperature across all specific state points. Throughout the study, the refrigerant pressure tends to rise as the air and water temperatures remain unset, causing the compressor to operate continuously. Consequently, the condenser temperature increases in tandem with the rising cooling water temperature. The primary goal of this approach is to ascertain the maximum temperature achievable within the heating system while ensuring it remains within the allowable working pressure limit of the refrigerant, set at 250 psi (1.72 MPa).

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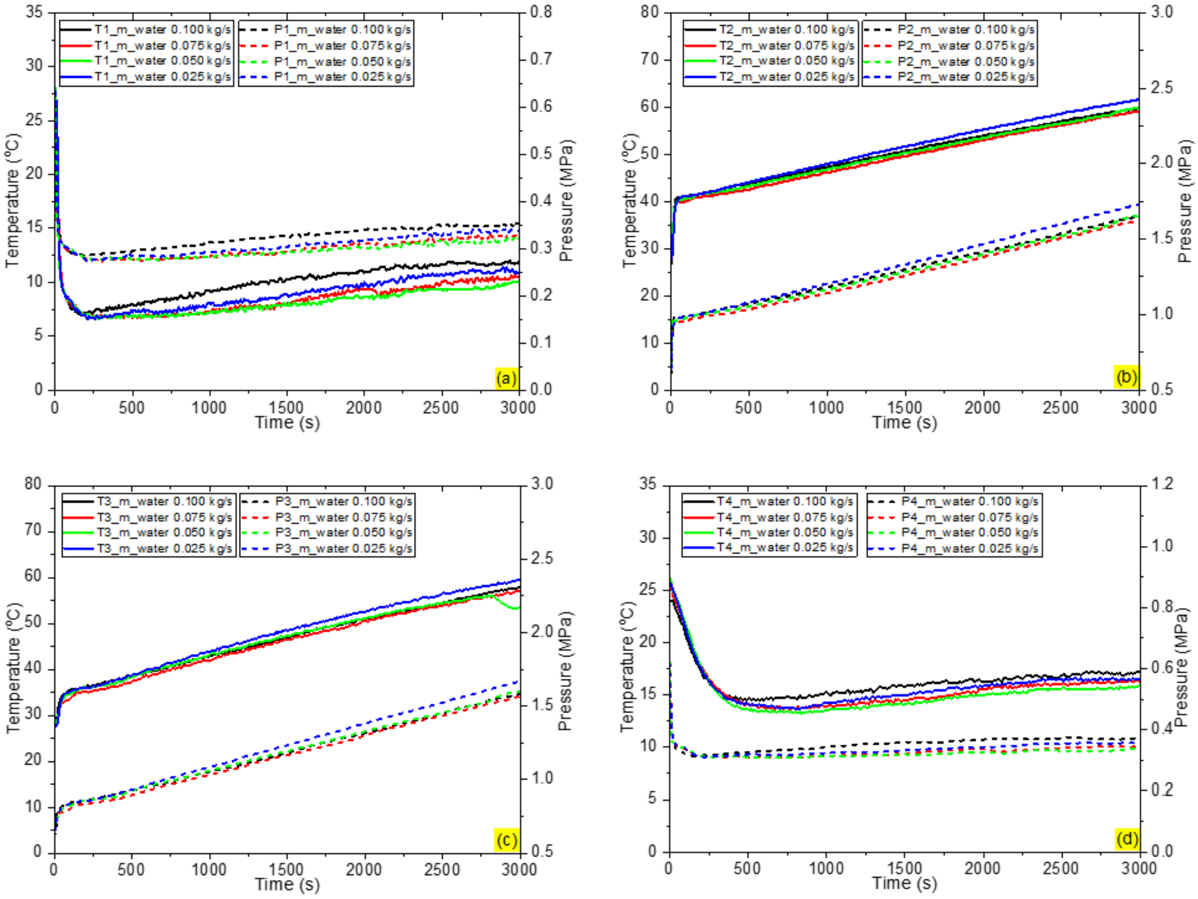

Figure 2. Refrigerant temperature and pressure behavior at various water mass flow rates: (a) Entering compressor; (b) entering condenser; (c) entering expansion valve; and (d) entering the evaporator.

3.2. Analysis of the Condenser

Within this study, the condenser operates by being submerged in circulating water, enabling the transfer of heat from the refrigerant to the water medium. Illustrated in **Figure 3(a)**, the refrigerant initially enters the condenser at approximately 40°C, while the water enters the heat exchanger box consistently at around 27°C across all investigated water mass flow rates. Initially experiencing a transient phase lasting approximately two minutes, the system gradually transitions towards a stable, steady state. Notably, the refrigerant's entry temperature into the condenser rises in direct proportion to the escalation in cooling water temperature. This temperature increase also correlates with the rise in refrigerant pressure, as evident in **Figure 3(b)**. Notably, the heat exchange process between the refrigerant in the condenser and the cooling water in the heat exchanger shell maintains consistent efficiency within the allowable refrigerant pressure limit of 1.72 MPa. The temperature differential between T_2 and T_5 observed at the onset of the test, at a refrigerant pressure of roughly 1.2 MPa, persists consistently until the refrigerant pressure reaches 1.7 MPa.

3.3. Analysis of the Evaporator

At the evaporator's inlet, as depicted in **Figure 4(a)**, solid lines indicate the ambient temperature, while dashed lines represent the temperature of the refrigerant entering the evaporator across all tested water flow mass rates. During the experiment, the ambient temperature slightly decreased as the testing occurred at night. The refrigerant temperature

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at the evaporator's inlet initially drops transiently until the 10th minute, after which it stabilizes. Once it reaches its lowest point, the refrigerant temperature gradually increases due to the rising water temperature in the heat exchanger. In **Figure 4(b)**, the refrigerant temperature exiting the evaporator is lower than when it enters, attributed to the gliding temperature effect. The air exits the evaporator at a temperature of 12–15 °C, compared to its entry temperature of around 24–27 °C. This occurs because the refrigerant absorbs heat from the air in the evaporator, facilitating its transition from a mixed phase to a vapor phase.

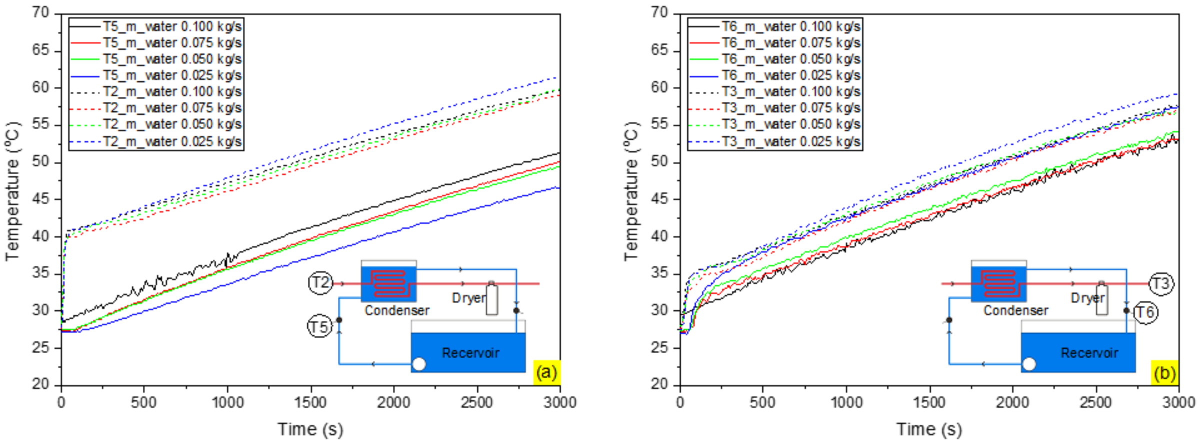

Figure 3. Temperature behavior in the condenser at various water mass flow rates: (a) Refrigerant and water entering condenser/HE, and (b) Refrigerant and water leaving condenser/HE.

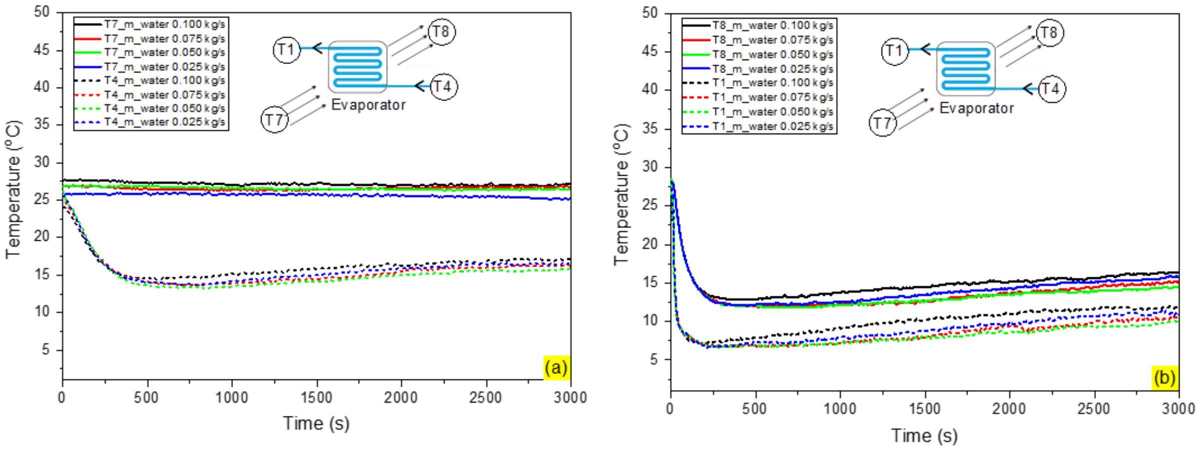

Figure 4. Temperature behavior in the evaporator at various water mass flow rates: (a) Refrigerant and air entering the evaporator, and (b) Refrigerant and air leaving the evaporator.

3.4. Heat of Condensation, Cooling Power, Heating Power, and EER

Since condensation occurs throughout the test, not all the heat needed for the refrigerant to evaporate is drawn from the air passing through the evaporator (refer to **Figure 5**). A portion of this heat is supplied by the condensation of water vapor, which releases a latent heat of 2,260 kJ/kg, equivalent to 40.8 kJ/mol [71]. Using the mass balance concept, the water vapor content in the air leaving the evaporator can be calculated using equations (12) to (14).

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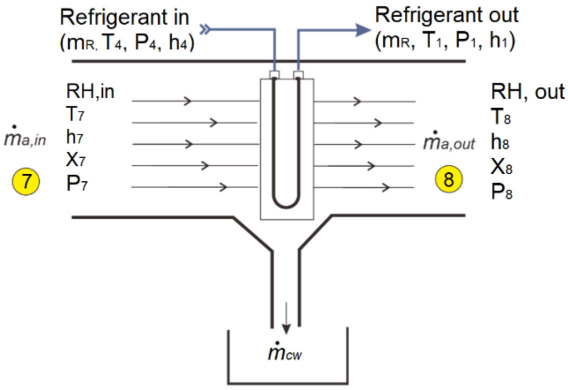

Figure 5. Mass balance on the evaporator.

$$\sum \dot{m}_{in} = \sum \dot{m}_{out} \quad (12)$$
$$\dot{m}_{a7} = \dot{m}_{a8} + \dot{m}_{cw} \quad (13)$$

The amount of condensed water is considered to be the loss of water vapor in the air leaving the evaporator. Thus, the water vapor content in the air leaving the evaporator can be calculated using equation (14) which is then used to calculate the air enthalpy value. In this research, the mass flow rate of air crossing the evaporator was 0.0452 kg/s.

$$X_8 = X_7 + m_{cw} \quad (14)$$

Condensation heat as presented in **Table 3** is not included in the cooling power calculation because it is not carried away in the air flow leaving the evaporator. By observing that the mass flow rate of air across the evaporator is constant, measured at 0.0452 kg/s, the actual cooling power profile produced is presented in **Figure 6(a)**. Meanwhile, heating power on the condenser side is presented in **Figure 6(b)** and q_t is presented in **Figure 6(c)**. Finally, we have measured the compressor power (W_c), electric blower power (W_{eb}), and water pump power (W_p) and obtained 1540, 41, and 23 Watts, respectively, for a total of around 1.6 kW. Assuming that the compressor power, electric blower power, and water pump power are constant throughout the test, the EER of this combined system is presented in **Figure 6(d)**.

Table 3. Loss of water vapor and heat of condensation in the air leaving the evaporator.

No	Water flow rate in condenser (kg/s)	Condensed water in evaporator (kg/s)	Air flow rate in the evaporator, measured (kg/s)	Loss of water vapor in the air leaving the evaporator, X (g/kg dry air)	Heat of condensation (kW)
1	0.100	0.245	0.0452	5.42	0.553
2	0.075	0.222	0.0452	4.91	0.501
3	0.050	0.183	0.0452	4.06	0.415
4	0.025	0.185	0.0452	4.09	0.417

3.5. Potential for Practical Implementation

Currently, almost all long-distance buses and tourist buses are equipped with A/C systems and toilets. On the one hand, air conditioning and toilet systems are oriented towards increasing comfort, but on the other hand, they also present new problems related to health and thermal comfort. First, the temperature inside the bus is too cold with low humidity, while indoor thermal comfort is more influenced by the heat index (HI) [6, 8, 72]. Second, low temperatures cause passengers to frequently go to the toilet to relieve themselves, which increases dehydration. Third, the water temperature in the bus toilet is very cold because it is collected from water condensation in the A/C evaporator, thereby reducing physical comfort. Fourth, cold bus toilets accelerate the growth of germs and bacteria. Therefore, the results of our research this time can be expanded to overcome these problems. The water circulation from the reservoir will help cool the condenser, while some of the heat released by the condenser will be received by the water circulation to provide hot water in the reservoir.

As is known, long-distance bus services (intercity buses) are very efficient public transportation. Buses have lower energy consumption per passenger kilometer than other modes of transportation [73]. Due to their efficiency, buses account for more than 80% of all public transport passenger trips worldwide [74, 75]. Furthermore, based on the Future Market Insight (FMI) report, the global market share of intercity buses is estimated to increase from 16.86 million dollars in 2022 to 25 million dollars in 2032. The growth of bus users is also reported to have continued to grow over the last few years [76, 77], which represents good practice in sustainable transport. From an infrastructure perspective, physical, mental, and health comfort during bus travel are important indicators of sustainable transportation [78]. Transportation service providers in collaboration with the car body industry continuously improve comfort services with the latest features, even technology to reduce the spread of viruses [79-83]. Therefore, the results of this research can be a consideration for car body companies to provide hot water that can be regulated in toilet reservoirs.

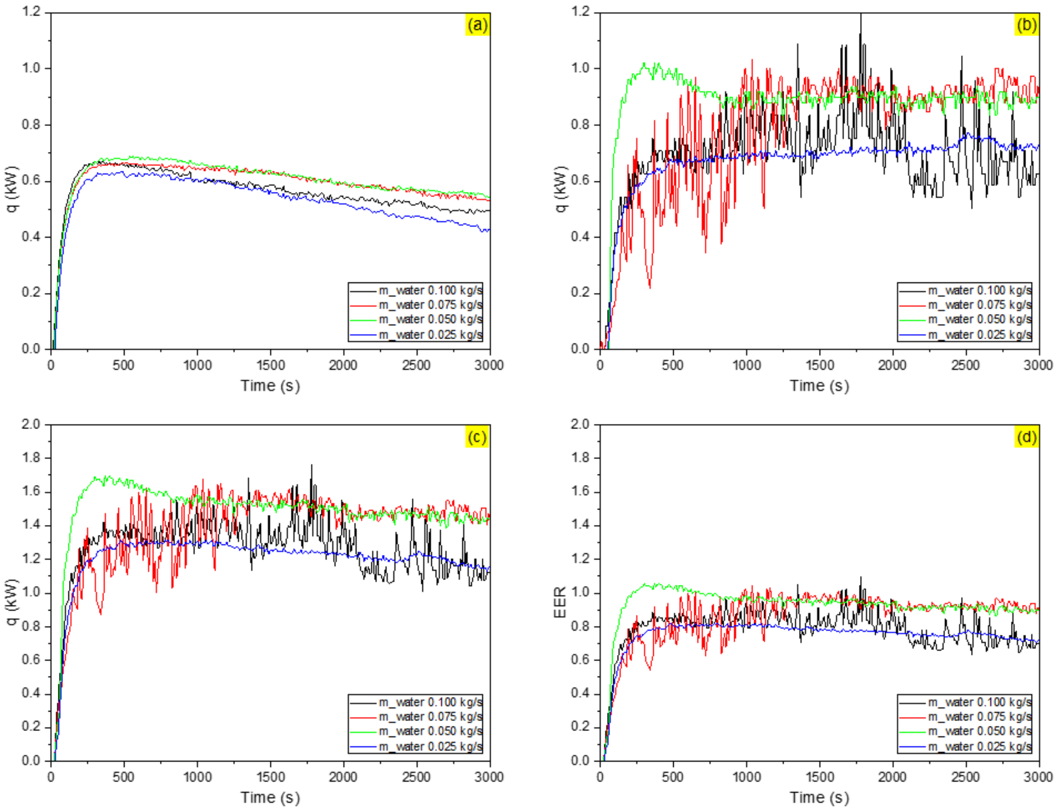

Figure 6. (a) Actual cooling power; (b) Heating power on condenser side; (c) Thermal energy; and (d) EER.

4. CONCLUSION

The significant contribution of this research is the innovative integration of air conditioning and water heating systems, to increase overall system efficiency, by converting wasted heat to the environment from the condenser into utilized heat to provide hot water in the reservoir. Using waste heat from AC condensers to provide hot water for bus toilets presents a practical solution that not only improves passenger comfort but also contributes to energy efficiency and sustainability. These findings have wider implications for the public transport sector, as long-distance buses are known to be a highly energy-efficient and environmentally friendly mode of travel. This research is in line with the increasing global demand for such services and ongoing efforts by transportation service providers to improve passenger comfort and safety. By providing hot water for the toilet reservoir, this integrated system offers a practical solution to improve passengers' overall travel experience.

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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